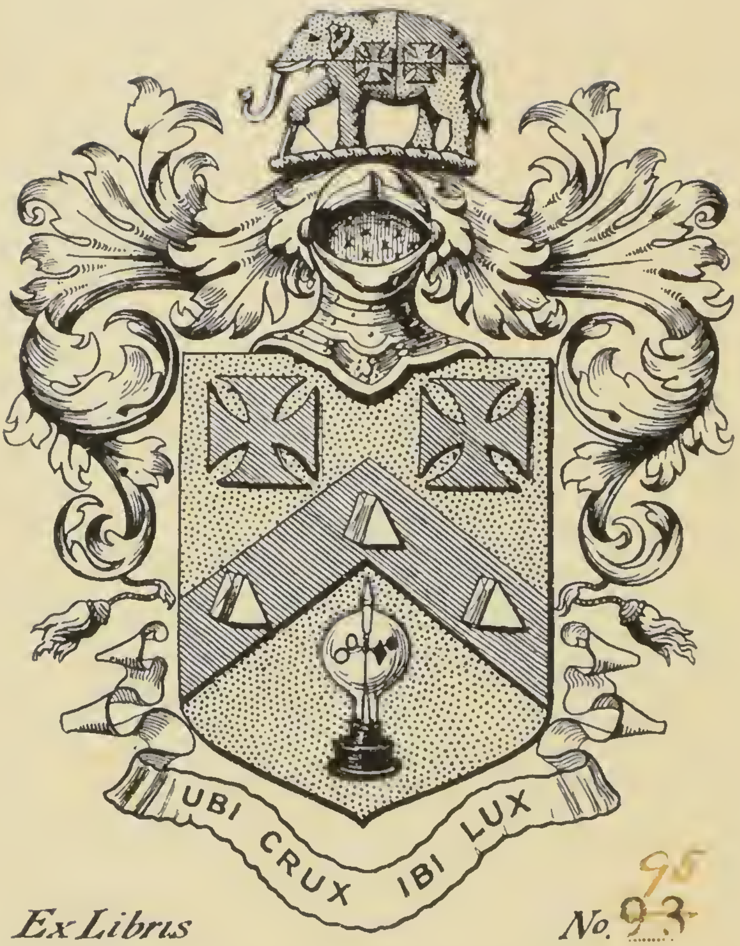
SCIENCE TEACHINGS IN LIVING NATURE

WATSON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IN

LIVING NATURE

A POPULAR INTRODUCTION

TO THE

STUDY OF PHYSIOLOGICAL CHEMISTRY
AND SANITARY SCIENCE

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CONTENTS.

INTRODUCTION.

THE present is, especially, an age of enquiry, for we do not now rest content with mere assertions, but accept them only when actually proved. How vast is the field of nature, and how immense, therefore, must be the domain of science! As in nature there are many different parts combined, or running closely together, to form an immense whole, so no *particular* science can fully explain the vast range of creation; and just as the light of the sun consists of several different lights combined, and as this combination is most suitable for the promotion of the various functions in the living section of nature, so the light which best enables us to explain the working of the universe, is composed not only of the light of one science, but of the radiations from all sciences combined.

> "One science only will one genius fit,
> So vast is art, so narrow human wit."

Notwithstanding the remark of a recent writer, who says—"We are staggered by the great shouting of men of science, who place a scientific above every other kind of education," it must be acknowledged that science is the only real foundation for true knowledge. The laws of nature are discovered by science, while art applies

them to useful purposes, and thus enlarges her field. Art is, therefore (as probably all things are), dependant first upon nature, and then upon science as a medium. Whatever the pursuit, whether agricultural or manufacturing, Science is the driving wheel, put into place by Art, and turned by the hand of Nature.

Of all sciences, perhaps chemistry is the most important, and should, therefore, be the most familiar, for (as one separated from the rest) it would explain the most things with which we are generally connected; and yet I believe the word chemistry is one which, to an ordinary person, frequently gives a very imperfect idea of that which it really represents. Instead of impressing him with its value, its general importance, and the connection which it bears to the many things, and phenomena occurring around us, it more frequently gives the idea of glass bottles up-side down; bad smells; explosives, which when touched destroy; or noxious substances, that always mean mischief.

A friend once said to me—"Chemistry is dry—positively dry; the words organic and inorganic, for instance, are words with very jarring sounds, and the whole science is composed of inharmonious language;" and, lest the well-known condemnation of those who have no music in themselves was presented as a fitting cap, to some extent the assertion may be admitted, but the argument is superficial and hardly worthy of note. It shows, however, what, I believe, is a very general idea in the minds of the general community, although chemistry is gradually becoming a subject in ordinary

school curriculum. Humboldt, in the great work of his declining years—*Cosmos: a Sketch of a Physical Description of the Universe*—says, "I take pleasure in persuading myself that scientific subjects may be treated of in language at once dignified, grave, and animated, and that those who are restricted within the circumscribed limits of ordinary life, and have long remained strangers to an intimate communion with nature, may thus have opened to them one of the richest sources of enjoyment of which the mind is invigorated by the acquisition of new ideas. Communion with nature awakens within us perceptive faculties that had long lain dormant; and we thus comprehend at a single glance the influence exercised by physical discoveries on the enlargement of the sphere of intellect, and perceive how a judicious application of mechanics, chemistry, and other sciences may be made conducive to national prosperity."

Chemistry has a dictionary which is becoming more and more comprehensive: the words it contains convey appropriate meanings, and when combined form the foundation for a true knowledge of the processes continually going on in nature. Everything in earth, in air, or sea, belongs to chemistry, and is constantly working under her dictation, to promote those familiar changes which we all admire. The rock which darts from beneath its verdant covering; the stream which dashes over the different coloured stones; the trees which hang over the stream reflecting upon it the varied tints of foliage; the bird singing its merry song upon its branches; and the fish which sports in its natural element as it winds its

way round the shaded nook, are each dealt with by that science whose title conveys such a dark and gloomy impression. As it deals with the composition of the air, the water, the rock, and the trees in the landscape, so it deals with the composition of man. The brain of the wise, the muscle of the strong, the bone of the skeleton, and the complexion of the beauty, are explained by the necessary application of chemical science; while the nature of the food which is taken to support them, the changes which it goes through before it does actually support them, and the decay after the life is separated from them by death, are explained by the same science.

"On earth there is nothing great but man," was the proud expression of the middle ages, and yet he is only a temporary being; one which in death promotes the same functions as the lowest creature he tramples beneath his feet. The degraded worm which crawls beneath the soil derives its substance from the earth; the offensive weed, or the cultivated plant that grows upon the earth, derives a necessary part of its structure directly from it; while "man, proud man," is an ultimate conglomeration of earthly dust. Thus, Lucretius writes, that "With good reason the earth has gotten the name of mother, since all things are produced out of the earth."

The earth, the air, the ocean, and the living bodies which inhabit the earth, are popularly considered as distinct divisions of nature, but nature cannot be divided; it is one immense system of mutual accommodation;

they cannot exist separated, for one is absolutely dependent upon another for its existence. The plant, as it grows, acquires from the soil and the air those various particles which, when united, form its complete structure: man, as he lives, acquires from the plant those particles which go to form his structure, but nothing flourishes for ever, and, when he fades away into the dim vista of the past, his substance returns to the earth.

Man is unquestionably the highest organism, and has the powers of thought most fully developed, for "the highest degree of organisation gives the highest degree of thought," but while possessing this advantage he is not independent, and cannot even say that the ephemeral insect lives without a purpose, since the humble creatures we so frequently despise are no doubt constructed to perform their part in nature. The many different forms of insects which crawl upon the earth, and which at first appear to us to deteriorate either the soil or the crop which grows upon it, may, on the other hand, be working out beneficial results; they may, for instance, at a particular time in their lives, be destroying certain plants or weeds which we do not desire to cultivate, and when they have so performed their duty, birds or other forms of life may destroy them to give place to future generations, or they may die naturally and return their component parts directly to the soil. While we try to imagine the desolate appearance of the earth without the beauty conveyed to it by the various and wonderful arrangements of colour which plant life

affords, and, as we notice its importance in the preparation of our food, let us not forget that it serves a most important purpose in the preparation of clothing for us. As the cotton plant forms a crop of cotton it purifies the air from noxious gases injurious to animal life. Wool is the product of animals fed solely upon plants. It may be truly said that from the earth each living body, whether plant or animal, comprises a step in the immense ladder of life that leads up to the highest form, which we ourselves comprise; and, as everything sooner or later comes to an end, we must descend the ladder, not step by step, but by one stride, and return to the earth from which we were formed.

In the following pages I propose to consider the chemistry of life, though by no means in full, for that would be an undertaking difficult to accomplish, and far beyond my present purpose, but rather to demonstrate some of the more important facts connected with everyday life, with which we should all be familiar, remembering that we are not independent units, but beings simply gifted with understanding, whose happiness largely depends upon the cultivation of it.

> "What is man,
> If his chief good, and market of his time,
> Be but to sleep and feed? A beast—no more.
> Sure, He that made us with such large discourse,
> Looking before and after, gave us not
> That capability and godlike reason
> To fust in us unused."

W. H. W.

BRAYSTONES, near WHITEHAVEN,
July 1879.

CHAPTER I.

> " You that seek what life is in death,
> Now find it air that once was breath.
> New names unknown—old names gone :
> Till time end bodies but souls none."
>
> BYRON.

THE origin of life, and the order in which its various forms have been observed upon the earth have been for long, and especially of late, the subject of much scientific enquiry and controversy, resulting in many different theories and speculations ; but with the almost general feeling that the absolute genesis of living matter is beyond human comprehension ; yet it is obviously impossible to say how far the mystery in which it is now obscured might be removed by scientific research ; for, in the words of Sir John Herschel, the character of the true philosopher is to hope all things not impossible, and to believe all things not unreasonable

In the chemistry of life, however, we have a more tangible foundation to work upon, and in its elementary study it offers a field as useful and interesting as does the primal origin of it. To the scientific enquirer the action of foreign substances on the phenomena of life affords a continuous range for experiment, while it is difficult to conceive any one uninterested in the causes

and the effects of those actions upon which his own life depends.

The more common actions, and those which are of most interest to the ordinary observer, have now been pretty fully considered, and our knowledge may be said to be definite upon many of them, though on others there is much room for further investigation and proof. The facts at present known concerning living action have been obtained by the joint efforts of the physiologist and the chemist from very early times; so, we must look forward for an extension of our knowledge to the same source, as Professor M'Kendrick remarked in his address to the British Association at Glasgow in 1876, thus:—" The physiologist must go hand in hand with the chemist. The chemist in his laboratory preparing certain substances, and building up new compounds, by those wonderful synthetic processes which are now the glory of his science, while the physiologist investigates the action of these. By united work who can tell what may be accomplished."

What are the characteristics of life?

Firstly, the reproduction of all living bodies from previously existing living germs, so that Hamlet's assertion that " the sun breeds maggots in a dead dog,"— and that by Helmont, in 1662, that mice may be produced from saw-dust and an old shirt, have finally been rejected in favour of the conclusions arrived at by Redi in 1668. Although 210 years have elapsed since this Italian philosopher asserted that there could be " no life without antecedent life," yet many years passed before

this opinion became anything like popular; and, indeed, quite recently the matter of "spontaneous generation" has been brought forward and advocated by Dr. Bastian, though well refuted by the experiments of Professor Tyndall and others. Redi's opinions were based upon experiment, and he looked upon speculative ideas, or theories without experiment, as not allowable in scientific investigation. His crude experiment with reference to the subject of the generation of life was a most simple one, one which is frequently performed in everyday life; and although not now considered sufficient in itself to warrant a precise conclusion, yet in those days it was; and fortunately the conclusion which Redi arrived at from it was one which is now generally accepted and confirmed by more accurate methods of research. He says, "Here is a piece of dead flesh. I simply expose it to the air during the warm weather of summer, and in a few days a number of maggots are produced upon it. It would therefore appear that these are generated by dead flesh. But if I take a piece of meat, as before, and expose it to the same conditions, but cover it by very fine wire-gauze, the meat may become putrid, but not a single maggot will be produced. This proves that I have kept something away from the meat which was the cause of the maggots being produced in the first case." Such was Redi's method of experimenting and reasoning. The blowflies, whose olfactory nerves are evidently most acute, smell the meat, they go to it, and, if possible, deposit their eggs, which are the germs from which the

maggots are produced. Redi, finding these germs deposited upon his wire-gauze, came to the natural conclusion that they were what the gauze intercepted, and which produced the maggots in the first instance (when the meat was simply exposed to the air), and he infers from this experiment, and others similar to it, that there can be no development of life without life previously existing. From these experiments the covers made of wire-gauze, now so generally used for covering meat, were originated, which, although allowing the air free access to it, prevent those other conditions which hasten its decay.

Taking a rapid leap over many theories and experiments bearing upon this subject, from the time of Redi to the present, and coming to the experiments of recent years, what do we find as a result? Practically the same conclusions. Over two hundred years ago, when Redi was busily engaged upon his researches into the origin of life, the appliances necessary for accurate experiments were not constructed. The microscope at that time was of a most elementary and inferior kind, so that while his experiments were necessarily upon those giant forms of life which we have just noticed, the microscope of the present day makes us familiar with those minute organisms which were then unknown, and of which there may even be many thousands in one single drop of water. Therefore, although Redi found that maggots were not produced in meat from which the flies were kept off by means of wire-gauze, we now find that although maggots are not produced, smaller

forms of life are; even in dead matter exposed to the air for a very *short* time. This fact by itself would lead us to reject Redi's conclusion, and to believe in "spontaneous generation," *i.e.* the production of living bodies from lifeless matter; but we have continued our investigations further. Dr. Bastian recently asserted that fungi may be produced from solutions containing only definite *chemical compounds*. Professor Tyndall's reply to this may be taken also as a reason for the production of organisms in meat exposed to the air and apparently kept from everything else. He shows that the air contains minute living organisms, cells of both plants and animals, in immense numbers, and that the fungi produced in the "solutions of chemical compounds" are due to the intervention of these—for the organisms are destroyed by heat, or they may be filtered out of the air by passing it through such a substance as cotton-wool, and when air, so purified, is alone allowed access to the solutions no living bodies are produced in them.

The name of Redi must ever stand most prominent in connection with the knowledge we possess of the development of living bodies, for he was the first who made it the subject of correct experiment, and upon his results the mass of work done in this direction up to the present day has been founded. It is not necessary to detail other arguments in connection with this subject, but to give it as the generally accepted opinion that one of the characteristics of living bodies is their reproduction only from living bodies previously existing.

Many diseases are spread by infection alone. This "infection" consists of living organisms which have the property of reproducing themselves to an enormous extent in the blood of human beings; while we suppose, further, that each individual infectious disease is spread by a particular kind of germ, just as a particular kind of animal or plant is produced from a germ or seed of its own kind.

Secondly, the germs from which all living bodies are produced are, in the first instance, minute; but, by the property which they possess of appropriating and assimilating matter from without, they increase in size by the formation of various organs, and this possession of organs being a general feature in the existence of living bodies they are commonly designated *organised bodies*, and thus distinguished from those containing the same elements in the world of lifeless matter.

Thirdly, after a time they lose the power which they previously possessed of appropriating the substances which surround them; their organised structures being gradually destroyed, while the combinations of the elementary substances of which they are composed are changed and become subject to the laws of *inorganic* chemistry. There are many other features by which bodies which are endowed with life may be distinguished from those which are not, but those already given are the more important; so that we now pass on to the consideration of some of the differences to be observed between the two divisions of life—animal and vegetable. They are these:—

1. The food of plants consists of inorganic substances, such as carbonic acid, ammonia, and water; while, on the contrary, that of animals consists of organic substances such as albumen, fibrin, fats, and starches, associated, as they are in nature, with small, though important, proportions of inorganic salts.

2. Plants contain considerable quantities of a substance called cellulose, while in animals this exact compound is only seldom found, and then in comparatively small quantities. It is the principal constituent of cotton fibre, and consists of $C_6 H_{10} O_5$.

3. Plants are not provided with a nervous system, while animals, with the exception of the very lowest forms, are.

We cannot fail to notice, as we observe the things around us, that certain definite conditions are absolutely necessary for the continuance of life in its various forms, and that it is to the absence of one or more of such conditions that the end of life is due. There must be in every instance a fluid, capable of nourishing the body; in constant circulation—a fluid containing the different substances requisite for the formation and sustenance of the various organs and tissues of the body. In the instance of animals such a fluid is called blood, and in plants it is called sap. The quantity and quality of this fluid is kept up by a supply of substances as food.

A constant supply of air is, as we all know, a necessary of life. If we "hold our breath" for a short time even, this is made painfully evident. It is not, however,

so very generally remembered that air should be pure when breathed, and especially, free from organic putrescent matters, to which the "close" smell of the air in confined rooms is due. The nature and action of these will be described hereafter. To the air we breathe the blood is frequently exposed, by which various substances no longer of value are cast out of the body; we are always more or less impure, and are thus constantly being purified. These impurities are evolved in the form of carbonic acid gas and watery vapour, from which plants derive much of their sustenance. The influence of plants on the atmosphere is, therefore, directly the opposite to that of animals, and it is owing to this important natural law that the atmosphere as a whole remains of one uniform composition—a composition which is more suitable than any other for the support of living bodies. This leads us to mention the fact that the actions involved in the respirations of plants and animals (but more especially plants) are considerably influenced by the external conditions, light and heat; indeed, the chief nutritive functions of plant-life are only exercised under the influence of solar light.

Apart, then, from the value of this as a medium by which we are enabled to see, solar light is of the greatest importance to us from a physiological point of view, and it is therefore spoken of as the

> "Prime cheerer
> Of all material things, first and best."

Solar light, and that derived from the burning of

gas, oil, or candles, must not be confounded. Light, as we have it direct from the sun, consists in reality of a number of different coloured lights (as they are seen in the rainbow), which, when combined, as they are, form a uniform white light. That derived from the burning of gas or oils is not so composed.

There are in the rainbow a number of different colours, which are separated from each other and made visible, but, so far as is at present known, it is only by one or two of these coloured lights that the *nutritive* functions of vegetation are promoted; namely, by the blue and violet rays, which are those possessing chemical action. Although these particular rays are supposed to be alone necessary in promoting the important vital functions just named, yet it is necessary that they should be diluted as they are in the day-light; so that if without action, the other rays are none the less important, and thus we have here one instance among many, of wonderful design in the whole of Nature's works. Ordinary artificial illumination, which we are obliged to resort to occasionally, does not contain the chemically active rays. It is therefore of no value in the promotion of healthy vital action, and in point of fact, when living in a room artificially lighted, we are, as regards health, living almost in absolute darkness. From what has been said, it follows that the value of light in relation to life depends, up to a certain point, upon the amount of the blue and violet rays which it contains. Solar light contains the largest *proportion* of these rays in the spring. Physiologists tell us that tadpoles, although

supplied with every other necessary of life except light, never become perfect frogs, and that people who live in dark rooms are more subject than others to nervous diseases. What is the effect of light upon the development of life? When decaying organic matter is infused in water, and the infusion set at rest for some time, minute animal bodies — animalculæ — begin to make their appearance, and may be easily seen in the infusion by the aid of a microscope of ordinary power. If a part of such an infusion be poured into a glass and exposed to the light, and another part kept in the dark, it will be found, after exposure for a day or two, that while that exposed to the light has developed a number of living bodies (than the motion of which nothing is more interesting when seen under the microscope), that kept in the dark has not. This shows that a longer time is necessary for the development of these living bodies in the dark than when exposed to the light.[1]

It has already been shown that daylight consists of different coloured lights combined together; but it should be added, that although it is considered that the blue and violet rays are those which are important in relation to life, yet the precise action of these and the others have been by no means fully investigated. As regards their action upon plant-life, one or two points

[1] It was shown, however, by Messrs. A. Downes and T. P. Blunt, in a paper read before the Royal Society on 6th December 1877, that light is prejudicial to the development of one of the lower forms of life called bacteria; a few hours' exposure to the daylight being in some instances sufficient to destroy the germs existing in an organic solution, while a similar solution kept in darkness developed bacteria freely.

have been made the subject of research by various experimenters, with the following general results :—[1]

a. The luminous rays retard the germination of seeds.

b. The rays having chemical action, to some extent, quicken germination.

c. Both the chemically active and the luminous rays are essential to the formation of chlorophyll (the green colouring matter of plants).

d. The chemical rays and luminous rays, without those affording heat, retard or prevent the development of the reproductive organs of plants.

e. The heat-giving rays facilitate the flowering of plants and the development of their reproductive organs.

Corresponding experiments on animal life are, I believe, at present wanting; but there is every reason to suppose that, to the lower forms, the results just given may be, to a certain extent, applicable.

With regard to heat as an external influence, its importance and effect are very evident from the increased vegetation in warm climates as compared with that in colder regions. In plants the sap ceases to perform its various functions under the influence of cold, and, as a result, leaves and other green herbage wither and decay; thus the bloom of summer gives place to the decay of winter.

Without considerable warmth no fruit or vegetable

[1] *Brit. Assoc. Reports* for 1850.

would ripen; the corn fields without the heat of summer would never produce that grandeur of colour we all so much admire; the bird's egg without the prolonged application of warmth would not produce the chicken; while the breeze which aids in carrying the air, vitiated by animal life, to the forests of purification, and which produces to the delight of the angler a ripple on the clear country stream, is produced by variation of temperature at different parts of the atmosphere. The sun, which provides us with that life-sustaining agent, light, supplies at the same time the heat, which, when required, promotes the germination of the seed, or ripens the full ear of corn for the harvest. How wonderfully are they connected! Artificially they can be separated, but the direct rays of the sun contain both, for they have mutual, though distinct, functions to perform.

The fireside in winter has a natural attraction for us when the cold is most severe, while even the sight of it has a pleasing effect.

Living bodies consist of a number of chemical substances, which have been derived from the atmosphere and the soil, but these substances, while forming part of living bodies, are more or less governed by living action —that is, they are not directly subject to the laws of ordinary chemistry as we understand them in the laboratory. There we can decompose and recompose substances almost as we desire; taking, for instance, sulphur and oxygen, we can easily combine them together, getting as a result the corrosive oil of vitriol, or

taking the metal copper we may unite it with oxygen to form the powdery oxide of copper, and finally this oxide of copper with oil of vitriol to form a neutral salt—sulphate of copper. But in our bodies substances do not always, as in this case, associate themselves according to the laws of chemical affinity, for chemistry, as we understand it, is here the servant of a superior power which regulates it.[1]

When studying the composition of animals from a chemical point of view, the human body is naturally selected, as that most perfect of all organised structures, for our conclusions apply to the lower forms equally, and indeed to a great extent to plants. As various as the different forms of animal life are, the zoology of almost every species being different, yet the chemistry of them is peculiarly uniform, for our bodies comprise the same elements as those of the fishes of the sea, the birds of the air, or the insects which crawl upon the earth, so that man may truly say to the worm, "Thou art my sister and my mother." Strangely, again, the science of nutrition in each class is not widely different, and man, elevated by his position in the *scale* of life, is humbled as he compares his similarity to and depend-

[1] I do not say that certain substances can only be formed by the intervention of vital force, which was an opinion held years gone by; on the other hand, it is only reasonable to suppose that all organic chemical substances may be artificially prepared by synthesis, but I say that there is a certain power (of which we at present know very little) which modifies ordinary chemical action in the arrangement of our component parts, and prevents their mutual decomposition as it would occur when the same substances were mixed together independently of a living organism.

ence on the lower forms. It has been well said by Milton that

> "To know
> That which before us lies in daily life
> Is the prime wisdom;"

and clearly the study of our own structures and those natural conditions which effect them is the surest foundation for such knowledge.

Of what, then, are we composed?

It is often desirable in describing the chemical elements and their combinations to use symbols by which they may be known and conveniently grouped together. The element *carbon*, for example, is represented by the letter C, and the element *oxygen* by O. Carbonic acid, which will be mentioned frequently farther on, consists of the two elements, carbon and oxygen—one equivalent of carbon combined with two equivalents of oxygen, so that we are able to express carbonic acid by the characters COO or CO_2. Similarly, water which consists of one equivalent of oxygen combined with two equivalents of hydrogen (the symbol for hydrogen being H) may be expressed by the letters HHO or H_2O.

An element is, of course, a substance which cannot be divided into two or more different substances, and is thus the opposite to a compound, which may be divided into two or more parts, each part having distinct properties.

The following elements are constituents of our bodies:—

	Symbol.
Oxygen	O
Hydrogen	H

		Symbol.
	Nitrogen	N
	Carbon	C
	Sulphur	S
	Phosphorus	P
	Chlorine	Cl
	Calcium	Ca
	Magnesium	Mg
	Sodium	Na
	Potassium	Ka
	Silicon	Si
	Fluorine	F
	Iron	Fe
In very minute quantity.	Copper	Cu
	Lead	Pb
	Manganese	Mn
	Aluminium	Al

Thus our bodies contain 18 elements in different proportions. The four last named being present in exceedingly small quantities, may be looked upon rather as accidentally present than as actually necessary, having, so far as is known, no definite function to perform, and being apparently introduced along with the food, and not at once discharged from the system, in which they have a tendency to accumulate. In like manner, arsenic and other mineral substances, evidently foreign to the economy, may be absorbed and deposited in various organs of the body; indeed, such has been the case, for "arsenic has been detected in the bones and hair of subjects to which small doses of it have been administered from time to time" (Taylor *On Poisons*).

Although the 18 elements already mentioned are

those found in the world of life, yet we know of 48 others in the whole of nature, thus making a total of 66. There may be, and in all probability are, more; but they have not at present been discovered, although the recent improvements in chemistry have resulted in the discovery of several very recently. The 48 elements existing in the world of dead matter, besides those already described as existing in living bodies, in order to make the list complete, may be enumerated here. They are as follows, arranged alphabetically:—Antimony, arsenic, barium, bismuth, boron, bromine, cadmium, caesium, cerium, chromium, cobalt, davyum (?), didymium, erbium, gallium, glucinum, gold, indium, iodine,[1] iridium, lanthanum, lithium, mercury, molybdenum, nickel, niobium, norium, osmium, palladium, platinum, rhodium, rubidium, ruthenium, selenium, silver, strontium, tantalum, tellurium, thallium, thorium, tin, titanium, tungsten, uranium, vanadium, yttrium, zinc, zirconium.

Many of these are very uncommon, and even by the chemist are very seldom employed, indeed, have been by no means fully investigated; they are, however, mentioned here as showing the components of the whole creation, so far as we at present know. They may be looked upon as designed for application to artificial processes at the hands of man, and, as an instance, the element iron has already proved the most important mineral product of the earth, and increased the wealth of this country with the greatest rapidity.

[1] Iodine is, however, found in considerable quantities in marine plants, from which it is prepared.

The elements oxygen, hydrogen, nitrogen, and chlorine, are gases when uncombined and at ordinary temperatures and pressure; in fact, up to this present year (1878) it was considered to be impossible, or at all events it was not known how, to liquify or solidify oxygen, hydrogen, or nitrogen; but, at the beginning of this year, this was accomplished by M. Raoul Pictet, by subjecting them to very intense cold and very high pressure.

The most important elementary substance is oxygen, which exists the most largely in our bodies. First we have it in the water, which constitutes fully two-thirds of the entire weight of the human body, and of which about 90 per cent is oxygen; then we have it as a constituent of the solid parts of the body; and finally, as the gaseous constituent of the air which supports life; for "by the air—in repose; the atmosphere; in movement, the wind—'we live and move and have our being.'" If we were to burn anything in the air, having weighed it before doing so, and were to weigh the products of its combustion, we should find, if they were carefully collected, that they weigh more than the substance did before being burned. This shows that, by burning, bodies take something from the air. If the substance be ignited in a limited supply of air it is found that after taking a certain quantity of something from the air it does not continue to burn: for instance, if we light a candle and cover it by a jar, the candle continues to burn a few minutes, according to the size of the jar, and then "goes out," because, by burning, it has taken

from the air that which is required to support combustion. It is oxygen. Bodies burn much more rapidly in pure oxygen than in the air, because the air only contains 21 parts of oxygen in each 100. Oxygen is also the supporter of life, for by our breathing precisely the same chemical action occurs as in the burning of a candle.

When oxygen acts upon any substance, as it does on iron—forming rust—it is said to oxidise it, and the compound formed is an oxide; thus the rust formed on iron by the oxygen combining with it is oxide of iron. Nitrogen is another gaseous element, and a constituent of the air. 100 parts of the air contain about 79 of nitrogen, in which it acts as a dilutant of the oxygen (in the same way that we use water to dilute ardent spirits), for without the presence of nitrogen the oxygen would be too powerful for animal respiration. Nitrogen is a characteristic element in the muscles of animals, being contained largely in the albuminous substances to be mentioned hereafter.[1] In combination with hydrogen, nitrogen forms ammonia, to which the refreshing odour of smelling salts is due. Ammonia is of immense importance in the nutrition of plants, while the albuminous substances, which consist of oxygen, hydrogen, carbon, and *nitrogen*, are similarly valuable in regard to animals. There cannot be flesh or blood without nitrogen: it is indeed a necessary constituent of plants, but its presence is more especially marked in the animal kingdom.

Hydrogen is also a gas at ordinary temperatures. It

[1] The white of an egg consists chiefly of albumen.

is the lightest body known, being $14\frac{1}{2}$ times lighter than air. When combined with oxygen it forms water. It may be obtained from water by passing steam through a red-hot iron tube—the oxygen of the water combining with the iron sets the hydrogen free. Hydrogen burns with a pale, almost non-luminous, flame; the product of its combustion being water. It does not support life when breathed, or combustion, but enters largely into the composition of most organic substances.

Carbon is a solid element. It exists in nature in three very different forms, namely, as charcoal, plumbago (or black lead), and the diamond. These substances when burned all produce the same compound, therefore we know that they are composed alike. The diamond is the purest form, and plumbago the most impure, being associated with various mineral substances. Carbon occupies a very large place in the composition of all organic compounds, and the number of carbon compounds themselves exceed the total number of all others at present known, while fresh compounds of carbon are being daily brought to light. The beautiful crystalline substance sugar consists largely of carbon, in fact it consists of nothing but carbon combined with the elements of water. We can easily make an experiment to show this. Strong sulphuric acid (oil of vitriol) has a great attraction for water, so that if some oil of vitriol be added to some sugar or syrup, the sulphuric acid will take away the water from the carbon of the sugar and leave the carbon as a black substance, which proves very clearly that the sugar consists largely

of carbon. It combines readily with oxygen, forming two compounds—according to the proportions in which they combine—namely, carbonic *oxide*, CO, and carbonic *dioxide*, or carbonic acid, CO_2, which is the most common, and that with which we are most concerned in considering the chemical actions occurring in living bodies.

The elements mentioned as constituting our bodies do not exist there as such, but in combination with each other as compound bodies, such as albumen, fibrin, and fats, in the organic section, and phosphate of lime in the inorganic. The most simple combinations formed by the chemical union of different elements are termed *proximate principles*, and accordingly we have either organic or inorganic proximate principles, of which those just mentioned are an important type.

Although the various elements, as they exist in our bodies, form such harmless compounds, yet they are the same elements which form the most explosive; and the difference in the properties of the compounds formed, is due to the difference in the manner and proportions in which they are combined together. The elements carbon and hydrogen, for instance, which enter so largely into the composition of the fats of our bodies and the starches of plants, are the same which form the "fire-damp" of the coal-mines, which, when mixed with air and ignited, produces the dreadful results which have been so frequently recorded of late. The elements phosphorus and hydrogen form the inflammable phosphuretted hydrogen gas which ignites as it bubbles

forth from boggy lands to produce the "Will-o'-the-Wisp," which has led so many weary travellers to destruction. Again, the elements nitrogen and hydrogen form the corrosive nitric acid or *aquafortis*. Fortunately, however, the elements produce in nature no compounds of a destructive character (with the exception of fire-damp), with which we are in the ordinary course of life connected.

Up to the year 1828, the word "*organic*" was applied to those substances which were believed to be formed *only* by living bodies—plants or animals—and which it was beyond the power of chemical synthesis to form. Such a distinction has, however, by the advancement of chemical knowledge—for chemistry of all others is *the* science of progression due to a firm basis—been rendered incorrect, for compounds then considered to be formed only by the intervention of living action can now be formed in the laboratory from the *elements* of which they are composed.

In the year just mentioned, Wöhler discovered that the compound urea, which was previously held to be a distinctive product of animal life, could be formed in this manner. An "organic" substance does not, therefore, necessarily mean a substance resulting only from the processes going on in living organisms, but the word "organic" may be, for convenience, applied to that portion of any dried animal or plant which is capable of being burned off by heat; the word "*inorganic*" including the remaining portion. It is in this manner that they will be frequently used farther

on. Organic compounds are constituted generally of a larger number of elements than inorganic compounds. As an instance of this, water, the most abundant *inorganic* compound found in nature, is composed, as has already been said, of two elements only; while the most abundant *organic* compounds (albumen and fibrin) are composed of five elements—carbon, hydrogen, oxygen, nitrogen, and sulphur, in minute proportion. It is also to be noticed that not only are there a large number of elements generally combined together to form one organic compound, but that a large number of equivalents[1] of each of the elements are present in *one* equivalent of the complete compound. It is owing to this fact in the chemical constitution of organic substances that they are more liable to decomposition or decay than the inorganic.

The organic combinations existing in living bodies may be arranged into two classes, namely, those containing carbon, oxygen, and hydrogen only, and those containing these with the addition of nitrogen, and small proportions of sulphur. Included in the former class we have fats, starches, sugars, and various acids, while in the latter we have compounds such as albumen, fibrin, and casein. The class containing carbon, oxygen, and hydrogen only, may, however, be conveniently divided into two—one of these divisions containing a much larger proportion of carbon and hydrogen than the other, and therefore called hydrocarbons, includes

[1] Equivalents are the proportions in which one element or compound unites with another to form a definite chemical salt or compound.

the various fats and oils; the members of the other division, in which there is a larger proportion of oxygen, being called carbohydrates, embrace various starches, sugars, and organic acids. The following shows the composition of some of the carbohydrates:—

Grape-sugar . . .	$C\ H_{12}\ O$
Starch	$C_6\ H_{10}\ O_5$
Citric acid	$C_6\ H_8\ O_7$

From this the application of the word "carbohydrates" (hydro: water), is well seen, since, as shown by the formulæ for grape-sugar and starch, they are simply constituted of carbon in combination, in different proportions, with water (oxygen and hydrogen); thus grape-sugar consists, as above, of six equivalents of carbon combined with six equivalents of water, while starch consists of the same amount of carbon combined with only five equivalents of water. The citric acid contains a larger proportion of oxygen, and hence has acid properties.

Our bodies are not, as a rock may be, composed throughout the same, but they are composed of various parts, the chemistry of each being somewhat different. The fatty tissues (therefore called the adipose tissues) consist of the fats, stearin, palmatin, and olein, and we ask, How are these substances accumulated? Are they simply appropriated from such substances consumed as food, or are they prepared in our bodies from dissimilar substances? Upon this subject great difference of opinion has existed, and perhaps to some extent still exists. One view is, that fats are *generated* in the ani-

mal body from the carbohydrates; the other is that they are not generated from these, but derived directly as fats. The first view is now generally received, and a very little consideration impresses us with its accuracy, namely, that animals have the power of forming and storing up in their bodies fat, from such substances as starch and sugar, with which they are supplied by plants. The chemical difference between fats and starches or sugars is simply, as we have already seen, that the former contain a less quantity of oxygen in proportion to the carbon and hydrogen than the latter. If we take away by any means a part of the oxygen from starch, we obtain fat as a result, and no doubt this action occurs in our bodies. A point which has considerable weight in support of this theory of the production of fat in animals is, that the carnivorous animals have little fat but much muscle, while the herbivorous have usually much more fat than muscle; and a still more weighty instance is the fact that bees fed upon sugar produce, necessarily by the assimilation of the sugar, large quantities of wax. The conclusion is that food most suitable for the production of fat is that consisting largely of either starch or sugar. This is brought to a practical illustration in the fattening of cattle, where the food employed is chiefly farinaceous,[1] aided by warmth and little exercise.

Besides the stearin, palmatin, and olein as fatty constituents of animal bodies, there is another, existing in comparatively small quantities, called cholestrin.

[1] Of the nature of starch.

100 parts of the blood have been found by Lecanu to contain 0·37 of this fat.

Having briefly examined some of the more important combinations of our bodies containing the elements carbon, oxygen, and hydrogen alone, we have now those characterised by the presence of nitrogen, which include the albuminous and gelatinous compounds of which our bodies are so largely composed. The gelatinous substances include gelatin proper, and a similar substance called chondrin. Gelatin is the word used in chemistry for what is commonly called *glue.* It is found largely in bones, from which it is obtained by boiling them in water; while chondrin is more especially a constituent of the cartilages, from which it is also extracted by boiling-water. Of all the organic substances of animal structures, the albuminous are certainly the most abundant, including, as they do, albumen, fibrin, casein, myosin, syntonin, and globulin, with other substances practically the same contained in the various juices. In plants a nitrogenous substance called gluten exists very largely, and is frequently called vegetable fibrin, from its similarity to the fibrin found in animal bodies.

Albumen is the most abundant albuminous body, the rest deriving their name from it (albuminous; like albumen). It exists largely in almost all the tissues of living bodies, while the most familiar form of it is the white of an egg. This fluid contains about 12 per cent of real albumen. Berzelius found in chyle $4\frac{1}{2}$ per cent, and in blood from $6\frac{1}{2}$ to 7.[1] The characteristic pro-

[1] Chyle is a milky-looking fluid, formed by the action of the pancreatic

perty of albumen is its coagulation by heat, a familiar instance of which we have in the boiling of an egg. This nitrogenous substance, along with fat and a minute proportion of inorganic matter, is converted into the various forms of animal tissues. In a bird's egg we have albumen along with phosphate of lime in the white, in the yolk we have a considerable amount of fatty substances in addition, so that these alone, by the influence of warmth upon the germ, are converted into a complex organism, in which there are bones, muscles, and nerves, complete, as we find them in the higher organisms. No doubt "simplicity is nature's strength," for were the process more complicated the result would naturally be less certain and probably not more perfect.

Casein closely resembles albumen in composition, as will be seen by the table given farther on, but in properties it is somewhat different, for while albumen is coagulated by heat, casein is not, and while casein is coagulated by the action of dilute acids, albumen is not. It is the nitrogenous principle contained in milk, where it exists apparently in combination with various alkaline salts, affording the nitrogen necessary for the support of life to the young of all mammals. Dr. Carpenter, in his *Manual of Physiology*, says that "all the liquids containing casein are such as appear to have it for their special function to supply formative materials for the rapidly-growing tissues, and we are therefore in all probability to regard this substance as still more closely

juice and the bile on the food in the first intestine, after being acted upon by the gastric juice in the stomach.

related to them than is albumen itself." Mulder was led to believe, from experiments, that albumen and casein were compounds of a principle which he called *protein*, finding that when they were dissolved in a hot solution of potash, and acetic acid afterwards added to the solution, that a greyish-white substance was deposited, identical in each case; and this substance he called fibrin. It is from this that they are commonly termed protein bodies or proteids, along with fibrin and the other similar nitrogenous compounds.

Fibrin may be obtained most abundantly from blood, but whether it exists there normally as such is doubtful, being more probably formed (in the state in which we know it—namely, as an insoluble compound) at the moment of coagulation—for blood coagulates when drawn from a living body and allowed to stand. In chemical composition the proteids albumen, fibrin, and casein are practically the same, as is seen by the following analyses by Mulder:—

	Albumen.	Fibrin.	Casein.
Carbon . . .	53·5	52·7	53·83
Hydrogen . .	7·0	6·9	7·15
Nitrogen . .	15·5	15·4	15·65
Oxygen . . .	22·0	23·5	22·52
Sulphur . . .	1·6	1·2	0·85
Phosphorus . .	0·4	0.3	None.
	100·0	100·0	100·00

Comparing these results, we see that the chemical difference between albumen and fibrin is that albumen contains $1\frac{1}{2}$ per cent less oxygen than fibrin. Acting

from this fact as a suggestion, the late Dr. A. H. Smee was successful in preparing fibrin by exposing albumen to the prolonged action of oxygen, and then, acting from the important evidence furnished by Dr. Smee, physiologists have since caused animals to breathe pure oxygen for some time, and found the result to be an increase in the amount of fibrin in the blood.

Myosin and *syntonin* are nitrogenous substances obtained from the muscular tissues of animals. Syntonin may be obtained by the direct action of hydrochloric acid either upon such tissues or upon the proteids. It is soluble in dilute hydrochloric acid, and is precipitated from the acid solution by alkalies. 100 parts consist of:—Carbon, 54·06; hydrogen, 7·28; nitrogen, 16·05; oxygen, 21·50; and sulphur, 1·11. Besides those already mentioned, there are various other nitrogenous substances which go to form parts of living bodies, though in much less quantity. Pepsin is one of these. It is the active principle in gastric juice, of which further mention will be made in Chapter IV. Ptyalin, the active principle contained in saliva, is also a nitrogenous substance. They probably act as ferments—the former (pepsin) on the nitrogenous part of the food in the stomach, the latter (ptyalin) on the carbohydrates. The action of ptyalin in digestion has been the subject of many experiments. When added to starch-paste the starch soon undergoes fermentation, the products of which are dextrin (gum) and grape-sugar; but this will be also more conveniently considered in Chapter IV.

Having considered shortly the organic compounds

existing most largely in our bodies, we have now to examine the inorganic compounds which exist along with them. It should be noticed that the organic substances already described do not exist separate from the inorganic, or in an absolutely pure state, for all the fluids and tissues of the body consist chemically of mixtures of the different organic substances, along with various inorganic salts. Strangely, these tissues and fluids, although there is a constant change going on of material, keep, as near as may be, of one composition, most suitable for the performance of their particular functions.

In considering the inorganic constituents of living structures we have to deal with the following elements: calcium, magnesium, sodium, potassium, silicon, iron, fluorine, sulphur, phosphorus, and chlorine, with oxygen and hydrogen as the elements of water, and the former as forming oxides with the elements before mentioned.

Nothing is perhaps more evident than the importance of water as a constituent of living organisms. Fully two-thirds of the human body consists entirely of water, and in the vegetable world it is even a more abundant material, for in the most largely cultivated plants as much as 85, and in some cases over 90, per cent is water, as follows :—

Potatoes . . .	75 to 78
Cabbages and turnips . .	90 to 92
Pears and apples . .	82 to 84
Strawberries and gooseberries .	85 to 90
Peas	13 to 15

Generally the amount of water contained in any part

of our bodies is found to be in relation to the activity of that part; and so in plants those portions which no longer play an active part in the growth or nourishment of the plant become hard and dry. Apart from its importance as a constituent of our bodies, its importance as a household necessity becomes to us every day more apparent, while the proverb, "Cleanliness is next to godliness" has become quite familiar.

When the elements potassium and sodium combine with oxygen they form oxides, known respectively as potash and soda. It is in the form of chlorides, sulphates, and phosphates, that these exist in our bodies. By chloride of sodium (common salt) we understand chlorine in combination with sodium; sulphate of soda—sulphuric acid in combination with soda; phosphate of soda—phosphoric acid in combination with soda; and similarly in the case of salts of other bases, as lime and magnesia. Liebig has shown that in the blood and other animal fluids, except milk, the salts of soda predominate over those of potash, while, on the other hand, the juice expressed from muscular flesh contains a larger proportion of the potash salts. Thus for each 100 parts of soda salts in the muscles of the ox there are about 280 of the potash salts, while in the blood of the same, for every 100 parts of soda salts there are only about six parts of the potash salts.

Calcium in combination with oxygen forms oxide of calcium, more commonly called lime. Phosphate of lime exists largely in bones: indeed the popular name

for phosphate of lime is bone earth, which is an impure form of it. It is also contained largely in the teeth of animals and, in smaller proportions, in the various fluids.

Beside calcium as phosphate of lime, we have it in various parts of the body, as chloride of calcium; and along with the phosphate in bone we have the carbonate and fluoride, the latter in small amount. The following table shows the composition of bone as fully as is necessary for general purposes:—

Phosphate of lime . . .	53
Carbonate of lime . . .	11
Fluoride of lime . . .	1
Phosphate of magnesia . .	1
Chloride of sodium . . .	1
Gelatin and other organic substances .	33
	100

Magnesium in combination with oxygen forms magnesia. When we burn a piece of magnesium wire, which gives off a brilliant white light, a white ash remains, which consists of magnesia (oxide of magnesium), due to the union of the oxygen of the air with the magnesium of the wire. It exists, as is seen by the above, in bones, in the form of phosphate; and it may be remarked that, whenever found in living bodies, it is accompanied by the corresponding salts of calcium, which usually predominate.

Phosphorus in combination with oxygen forms phosphoric acid. It exists, as has already been said,

in union with lime, magnesia, soda, and potash, in the various tissues (especially the nervous tissues) and fluids of our bodies, but most largely in bone, in which it was first discovered in the year 1769, and from which it is now manufactured. It is very inflammable, being burned (oxidised) gradually by exposure to the air at ordinary temperatures, emitting a white smoke. It ignites, and burns rapidly, by the application of very little heat, such as may be produced by slight friction. Although, when combined as above, phosphorus is an important constituent of the organisms of both plants and animals, yet when administered in the free (that is uncombined) state it is a most active poison.

Sulphur has been known from the remotest times. It exists in small proportions in the different proteids. The offensive smell of a decayed egg is due to the sulphur having combined with the hydrogen, thus forming sulphuretted hydrogen, the gas to which indeed the offensive smell of decaying animal and vegetable substances is usually due.

Chlorine in combination with sodium, magnesium, and calcium, is present largely in the various fluids of the body, especially as chloride of sodium, which indeed forms half the weight of the total saline matter in the blood. Chloride of sodium (common salt) is of immense importance in the digestion of food, especially the albuminous. No doubt the hydrochloric acid found, as we shall presently notice, in the gastric juice, which acts upon the food in the stomach, is prepared from the chloride of sodium taken along with the food, and

therefore the importance of a supply of salt is at once evident, beyond the mere gratification of the taste.

Iron, as oxide of iron, is contained in small, though important quantity, in the blood and in several of the fluids, which act in the process of digestion. *Fluorine* exists chiefly in the teeth and bones of animals in combination with calcium as fluoride of calcium. Berzelius found in the enamel of human teeth 3·2 per cent of fluoride of calcium, and in the enamel of the teeth of oxen 4 per cent. Mr. A. Jarisch has recently published (*Chem. Centr.* 1877·7) a series of analyses of blood-ash, which shows the chief inorganic constituents of the blood and the proportions in which they exist. Thus in 100 parts of the ash (the acids and alkalies being combined with each other when existing in the blood)—

	Man.	Horse.	Cow.
Phosphoric acid	8·82	8·38	4·98
Sulphuric acid	7·11	6·31	6·17
Chlorine	30·74	28·63	35·12
Potash	26·55	29·48	10·74
Soda	24·11	21·15	37·44
Lime	0·90	1·08	1·15
Magnesia	0·53	0·60	0·18
Oxide of iron	0·16	9·52	9·24
Carbonic acid	—	1·30	2·97

The substances now described are those essentially present in our bodies, and therefore, in reality, the substances of which our bodies are composed, but there are other substances present which may be looked upon as derived from these by the wear and tear continually going on in the economy. These derivates—the more

important of which are carbonic acid, water, and urea—are therefore to be found chiefly in the excretions. The two former will be considered more appropriately in Chapter III. in connection with the respiratory process. *Urea*, about one half of which consists of nitrogen, is evidently the result of the disintegration of the proteid substances which is constantly occurring in proportion to the energy expended or work done. Urea is chiefly found in the fluid excrement from animal bodies, and its composition is shown thus, CH_4N_2O.

Finally, the whole of the elements which make up our corporeal structures are derived from the food. The acids and alkalies, the salts, and the various organic substances, such as albumen, fibrin, gelatin, and fat, are all derived from this source. The air supplies us with no part of our constitution, but is made use of in daily life in a process by which various effete matters are discharged from our bodies—a cleansing process—respiration.

CHAPTER II.

"Bright and glorious is that revelation,
Written all over this great world of ours,
Making evident our own creation
In these stars of earth—these golden flowers."

LONGFELLOW.

THE connections between plants and animals are unmistakably very close, and the study of the one would therefore be very incomplete without much consideration of the other. A distinction between the food of plants and that of animals has already been made, namely, that while plants do not, with one or two peculiar exceptions, make use of any substance as food which is not included in the *inorganic* class, animals are nourished chiefly by the organic compounds. It follows then, that until organic substances have undergone decomposition, and thus become subject to the laws of inorganic chemistry, they are not available as plant-food. Fungi, a class of plants of which mushrooms are a familiar type, are a peculiar exception to the rule, for their breathing functions resemble those of animals much more closely than those of plants. They have the power of assimilating organic substances as food, and while they absorb oxygen from the air, and evolve carbonic acid, other plants do the reverse. Excepting oxygen, the elements mentioned as the ultimate prin-

ciples of organic matters (oxygen, hydrogen, carbon, and nitrogen) are not capable of affording nutriment to vegetation if supplied in their free state—that is uncombined,—it is absolutely necessary that these elements should be presented to the plant in the combined state, and it is further essential that these combinations should be conveyed to the plant in either the gaseous or fluid form, plants being unable to absorb for assimilation substances supplied to them in the solid state.[1]

Many of the elements made use of in the sustenance of plants are, however, as such, solid; but, when combined, they occur either gaseous, fluid, or as solid compounds soluble in water. Thus, carbon, which is solid, forms by combination with oxygen carbonic acid, CO_2 which is gaseous. Plants have at their disposal in the moving air a never-ceasing supply of nutritious substances, while in the soil they meet with compounds in the liquid form which are equally necessary for their support:—

> "Fixed like a plant on its peculiar spot,
> To draw nutrition, propagate, and rot."

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[1] Mr. Darwin's work on *Insectivorous Plants* is probably the most important recent contribution to physiological botany. The peculiar and interesting character of these plants is, that they act very similarly to animals in the digestion of their food. They are capable of catching insects, of digesting them, and of assimilating the nutritious substances of which they are composed. The common sun-dew, *Drosera rotundifera*, is an example of this kind of plant. The leaves are covered on the upper surface with long-stalked hairs, which serve as traps for catching the insect, and from the ends of them a digestive fluid is secreted. Mr. Darwin calls these tentacles, and when they are irritated, as they are by catching an insect, they move, and gradually embrace it. The secretion is then poured out,

The element carbon is certainly the most interesting of all elementary substances; for, if we imagine carbon as struck off the list of elements, of which there are 66 at present known, we must also imagine the world without any living thing; destitute of all forms of vegetable life, from the most minute seed to the gigantic tree which towers high above our heads; without any animal body, from the simple germ to the most complicated muscular and nervous arrangement. Vegetable produce contains on an average as much as 46 per cent, nearly half its weight, of carbon. From this we can at once have an idea of the immense amount of carbon which is annually removed from the land by crops of various kinds; and when we consider, in addition, the amount accumulated by the wild herbage which clothes the soil in every situation, we can appreciate even more fully the very large supply from which this carbon must be derived.

Messrs. Lawes and Gilbert's experiments on this subject, at their experimental farm at Rothamstead, are interesting. They give the following numbers from one acre of land obtained under the ordinary system of cropping:—

	Pounds per Acre.		
	Wheat.	Barley.	Oats.
Gross Produce . .	4800	4580	4172
Dry Organic Matter .	3869	3714	3328
Carbon . . .	1734	1663	1495

From what source do plants obtain the carbon of which they are so largely composed, and what is that

and it is observed that by this fluid a fly or other nutritious substance, such as a piece of meat, is digested, as it is in the stomach of an animal.

abundant material from which the carbon constituting all vegetable matter is derived? For many years, and up to a comparatively recent date, it was supposed that plants derived their carbon chiefly from organic substances, such as humus,[1] present in the soil. It was held that the organic matter of the growing plant was derived directly from pre-existing vegetable matter present in the soil; but it is now known, as has already been said, that plants do not make use of organic matter as food, except in very exceptional instances. The celebrated French chemist Boussingault was the first to show the error in the old view of vegetable nutrition. He grew plants from seeds in soil artificially prepared, free from carbonaceous organic matter, and they not merely grew, but grew luxuriantly. The idea of the accumulation of carbon by plants being from the soil is at once dismissed, and our attention is next drawn to the rain, by which they are supplied with water, and to the air. Water, when pure, cannot supply carbon to plants, because it consists of oxygen and hydrogen only; but in nature we never find it in an absolutely pure state, and generally there is as an impurity some compound of carbon in small quantity. In the drainage water from boggy lands we have carbon combined as peaty matter, yet such would be quite inadequate to the immense supply which plants require. Rain-water, as it falls from the air, also contains carbon: in passing through the atmosphere it acquires certain substances, and one of these is carbonic acid. The amount present

[1] Partly decayed vegetable matter.

in rain-water is very small, but it points to the air as a more abundant source.

In the year 1674 Mayhow, then a student at Oxford, proved the air to be a compound or a mixture, and not an element, as was previously supposed, along with fire, earth, and water; but until one hundred years later the correct composition of the atmosphere was unknown, when Lavoisier correctly pointed out its chief constituents. We have in the air a mixture of oxygen, nitrogen, carbonic acid, ammonia, and aqueous vapour, with other gases in very small proportions, and, indeed, minute solid bodies arising from manufacturing operations, etc. 100 parts of atmospheric air may, for practical purposes, be said to consist of oxygen 20·96, nitrogen 79, and carbonic acid 0·04. The amount of ammonia in the air, although, as we shall presently see, of immense importance in relation to plant-life, amounts to only about one part in one million.

The constituents of the atmosphere are simply mechanically mixed—not chemically combined—and although some of the gases are heavier than others they do not rest upon one another, as was once supposed, in layers according to their specific gravities, but mingle together, a uniform mixture being the result.

Independently of the motion given to them by the wind, gases possess the property of diffusion, first described by Dalton, and it is owing to this diffusive power which they possess that specimens of atmospheric air collected from different open situations are almost identical in composition; indeed, were it otherwise, the

air of towns would be so impure as to be unfit for the support of life, owing to the large amount of combustion going on and the respiration of animals. These are the two sources from which the air obtains its carbonic acid, which is formed when any substance containing carbon is burnt in a free supply of atmospheric air or oxygen gas. Coal, oil, wax, and wood, all consist largely of carbon, therefore, when any of these is burnt, carbonic acid is produced and passes into the atmosphere. Seeing that these productions of carbonic acid are constantly occurring, and yet the atmosphere has, since the dawn of animal life upon the earth, been apparently the same in composition, it is evident that some counteracting agency must be at work in order that this uniformity may be kept up. Such an agency is living plants, and thus while serving the direct purposes of supplying animals with food and of beautifying the face of the earth, vegetation serves the important purpose of maintaining a pure atmosphere, suitable for continued respiration.

Plants absorb carbonic acid from the air, divide it, under the influence of solar light, into its constituents—carbon and oxygen—retain and assimilate the carbon from which their various chemical constituents and organs are to a large extent formed, and return to the atmosphere the oxygen on which animals are dependant for their support.[1] We cannot actually see this process of decomposing carbonic acid going on by plants, but that the light from the sun plays an important part in

[1] This is how such a process might go on. The carbonic acid absorbed might combine with the elements of water to form a carbohydrate, at

the growth of vegetation is evident by the fact that if we take a healthy growing plant from the light and keep it for some time in the dark, the fresh green colour of the leaves disappears, and the plant gradually withers. Again, we may notice that a plant growing in a cellar, or other dark place, into which there is only a small window or other opening by which light is admitted, will grow towards the window, and if allowed may grow directly through the opening, as if trained by artificial means. Daylight being necessary for this decomposition of carbonic acid by plants, night is the time of comparative rest for plants as well as for animals.

How does sunlight affect this process? No very reliable evidence has yet been obtained with regard to the actual effect of solar-light in the promotion of the functions of plant life, but the following reasoning may give some idea of the nature of it.

When charcoal (carbon) is burnt in the air it unites with the oxygen of it and forms carbonic acid. By this combination what we call "energy" is developed in the form of heat, and thus the charcoal becomes red hot. Energy may be in the form of light or heat; they are both "energy," but in different forms, just as ice and steam are both water. For the decomposition of this carbonic acid, as it takes place in plants, as much "energy" must be applied *in the form of solar-light* as

the same time liberating oxygen into the air, according to the following equation:—

$$\overbrace{6\,CO_2}^{\text{Six equivalents of Carbonic Acid.}} + \overbrace{5\,H_2O}^{\text{Five equivalents of Water.}} = \overbrace{C_6\,H_{10}\,O_5}^{\text{Carbohydrate.}} + \overbrace{6\,O_2}^{\text{Oxygen liberated.}}$$

was developed in its production in the form of heat—that is, when the carbon and oxygen combined together. The leaves of plants are generally green, and it is found that they contain a considerable amount of a substance called chlorophyll—a green substance, as its name implies. This compound aids the light in decomposing the carbonic acid in plants, also in decomposing the water which surrounds them in the form of vapour in the air, and thus forming in them the carbohydrates; for where the chlorophyll does not exist the decomposition of these compounds does not occur. It exists in the form of minute granules in the leaves and other green portions of plants—in fact, the green colour of vegetation is due to this compound. Light, as we receive it from the sun, has, therefore, most important functions to perform in the economy of nature, and although we can scarcely go so far as the poet, gifted with the exuberant feeling of the interminable diversity and beauty of nature, in saying that the sun

> "Turns with splendour of his precious eye
> The meagre cloddy earth to glitt'ring gold,"

yet it is unmistakably true that the golden flowers which form such a pleasing garment of variety, depend upon the light of the sun for their development and growth. Although plants absorb carbonic acid and emit oxygen in the day, at night they do the reverse; they absorb oxygen and emit carbonic acid. From this it would naturally appear that that purification of the atmosphere which plants accomplish in the daytime would be counteracted by them during the night; but

such is not the case, inasmuch as the amount of carbonic acid absorbed by plants exposed to the light is much more than that evolved by them in a corresponding period during the night.

The amount of oxygen absorbed in the dark varies in different plants. De Saussure found that the leaves of the white poplar during 24 hours absorb 25 times their volume of oxygen, those of the common oak about 14, while those of the fir only 10 times their volume. Those leaves, in fact, the colour of which fades most rapidly, absorb more oxygen in a given time than those with colour more lasting. This is well seen from De Saussure's experiments also, which show that while the leaves of the poplar (which fade somewhat soon) absorb 25 times their volume, those of the holly (remarkable for the permanency of their green colour) imbibe only about $2\frac{1}{2}$ times their volume.

Although the carbon of plants is derived mainly from the carbonic acid contained in the atmosphere, yet the same compound exists, though less abundantly, in the soil (as is shown by the following results by Boussingault and Lewy), and of this they do not fail to avail themselves :—

Description of Land.	Parts of Carbonic Acid in 10,000 parts of Soil.
Field recently manured	221
Do. do.	974
Field of carrots	98
A vineyard	96
Forest land	86
Do. loamy subsoil	82
Do. sandy subsoil	24
Garden soil	364

Plants derive oxygen and hydrogen from water. The air always contains water in the form of vapour as a result of evaporation from the sea and water on the earth's surface. Sometimes the water in the air is much more than at others, according to the warmth or coldness of the air ; the warmer the air the more watery vapour it is capable of holding in solution. The deposits of dew, so valuable to the growth of plants, are caused by the bodies—plants themselves—on the earth's surface becoming cool, and thus causing the vapour contained in the air near them to be thrown out of solution and condensed as dew. When the air becomes very cold these deposits of dew assume the form of hoar frost. Plants, therefore, not only absorb the water from the soil which conveys various nutritious substances to them of an inorganic nature, but they absorb it from the air by their leaves, and it thus affords a supply of oxygen and hydrogen, which goes to form, along with carbon, such a variety of interesting compounds, of which it might well be said, there are

> "Many for many virtues excellent,
> None but for some, and yet all different."

The nitrogen in plants exists chiefly as gluten, which is composed almost exactly the same as the proteids—albumen and fibrin—so largely formed by animals ; indeed gluten is commonly called vegetable fibrin. It is contained largely in the seeds of plants, and is the nutritious substance contained in flour and bread—the material supplied by plants for the formation of animal muscle. By kneading dough prepared from

flour under a slight stream of water we are able to separate the starch from the gluten, the starch being washed away, and the gluten remaining as a tough elastic substance of a grey colour, which, when dried, is hard, and resembles horn in appearance.

From what source do plants derive their nitrogen? It has already been shown that the air contains 79 per cent of nitrogen, but considerable difference of opinion exists, or perhaps, more properly, has existed, as to whether this free nitrogen of the air exerts any important action on vegetation—whether plants avail themselves of it as food or not. Various experiments have now been made which show that the free nitrogen of the air is not available as plant food, while a few experimenters assert that it is available to a very slight extent. When it is considered, however, that if plants did use the free nitrogen contained in the air as food, the normal composition of the atmosphere would soon be changed, and the air rendered unfit for animal respiration, which evidently it is not, the natural conclusion is that the nitrogen of the air does not serve as plant food.

When nitrogen and hydrogen combine together, in the proportion of one volume of the former with three of the latter, the compound called ammonia, NH_3, is formed. It is a colourless gas, with a peculiar odour, characteristic of "smelling salts." When any organic substance containing nitrogen and hydrogen decomposes or decays, these two elements enter into combination and form ammonia, for it is owing to such decay that the air contains it. From this ammonia contained in the

atmosphere (although present in so small an amount as one part in 1,000,000) plants obtain the nitrogen, which goes to form the different nitrogenous compounds of which they are productive—notably gluten. In the instance of cultivated plants the supply is usually increased by the addition to the soil of some compound containing it in an available form to be immediately considered. It has been roughly estimated that 90,000 cubic miles of rain falls upon the earth in the course of a year, and that it contains, and therefore supplies to the soil, no less than one and a half millions of tons of ammonia. There is also another constituent of the air which affords nitrogen as food to the growing plant: it is oxide of nitrogen, nitric acid. Gopelsröder made a number of experiments at Basel showing the amount of nitric acid contained in rain or snow water. His results are as follows (Zeitschr, *Anal. Chem.* x. 259; xi. 16):—

Months 1870-71.	Nitric acid contained in 1,000,000 parts of collected Rain or Snow Water.	
	Maximum.	Minimum.
October 1870 . . .	13·6	Trace.
November ,, . . .	1·2	0·5
December ,, . . .	5·3	0·4
January 1871 . . .	5·3	3·1
February ,, . . .	4·4	2·2
March ,, . . .	12·3	2·6
April ,, . . .	4·6	2·2
May ,, . . .	10·0	2·2
June ,, . . .	6·2	2·3

Dr. R. Angus Smith, F.R.S., has examined the rain

water fallen in various districts.[1] Although the ammonia and nitric acid are of special interest here, the other impurities found are also given :—

RAIN WATER AVERAGE IMPURITIES PER 1,000,000 PARTS.

Where collected.	Hydrochloric acid.	Sulphuric acid (anhydrous.)	Sulphuric acid for 100 of hydrochloric acid.	Free acids calculated as sulphuric.	Ammonia.	Organic ammonia.	Nitric acid.
Ireland, Valencia . . .	48·67	2·73	6	none	0·18	0·03	0·37
Scotland, five coast country places west . .	12·28	3·61	29	0·14	0·48	0·11	0·37
Scotland, eight sea coast country places east .	12·91	7·66	59	2·44	0·99	0·11	0·47
Scotland, twelve inland country places . .	3·38	2·06	61	0·31	0·53	0·04	0·31
England, twelve inland country places . .	3·99	5·52	138	none	1·07	0·11	0·75
Scotland, six towns . .	5.86	16·50	282	3·16	3·82	0·21	1·16
Darmstadt	0.97	29·17	2998	1·74			
London	1.25	20·49	1645	3·10	3·45	0·21	0·84
Manchester	5.83	44·82	768	10·17	5·96	0·25	1·01
Glasgow	8.97	70·19	782	15·13	9·10	0·30	2·44

While the supply of ammonia is augmented in agricultural practice by the application of sulphate of ammonia to the soil, the supply of nitric acid is increased by the use of nitrate of soda.[2] Both of these compounds afford nitrogen for the nutrition of plants. Although the compounds of ammonia and nitrate of soda are valuable, when duly applied, in promoting the growth

[1] Sixth and Seventh Report of the Inspector under the Alkali Act of 1863.

[2] Much of the ammonia, however, is oxidised in the soil and converted into nitric acid.

of plants, yet, as in the case of other salts, when applied in large quantity they act injuriously. An instance lately came under my notice where a compound was sold for killing weeds, which consisted of nothing more than sulphate of ammonia and ordinary sand in equal parts.

The elements carbon, oxygen, and hydrogen, go to form an immense number of different compounds, indeed, the carbon compounds far exceed the number formed by all the other 66 elements at present known. New compounds of these three elements are being daily brought to light, and afford subject for endless investigation. Some of them, although possessing properties totally different from each other, are, so far as chemists are able to determine by the most accurate methods of research, identical in composition: and we are therefore led to conclude that the difference in properties is due to the *arrangement* only of their component parts, thus starch and gum, for instance, are precisely the same in chemical composition, both being expressed by the formula $C_6 H_{10} O_5$.

Plants produce in large quantities the carbohydrates starch and sugar, indeed the starches are the most abundant vegetable products. Many of the much-cultivated plants are very largely composed of starch.

1 lb.	of rice	contains	12	ounces	of starch.
,,	wheat	,,	9½	,,	,,
,,	maize	,,	9	,,	,,
,,	barley	,,	7½	,,	,,
,,	oats	,,	6½	,,	,,
,,	peas	,,	5½	,,	,,
,,	potatoes		3	,,	,,

When examined by the aid of the microscope, starch is found to be granular. The granules differ in size and shape according to the kind of plant from which the starch is obtained, and from this fact we have a ready means of detecting the adulteration of the more expensive starches with the inferior. This is a very fortunate circumstance, for chemical analysis does not assist us in detecting such adulteration, inasmuch as there is no chemical difference between the various starches, but a characteristic variation in their organised forms, which the microscope so well reveals. The changing of starch into sugar is very extensively carried on in the organisms of both plants and animals; first into dextrin or gum and then into sugar. The chemical changes which take place in the germination of seeds include this change; the starch changes into sugar by the appropriation of water, and then, as the germination proceeds, the sugar becomes changed into carbonic acid and water. The sweetness of every fruit and vegetable is due to this conversion, and in digestion in animal bodies the formation of sugar from starch is first accomplished. From a chemical point of view the change is very simple, for, by the mere combination of the elements of water (and in the same proportions as they exist in water) with starch, sugar is formed, thus,

$$\underset{\text{Starch.}}{C_6H_{10}O_5} + \underset{\text{Water.}}{H_2O} = \underset{\text{Grape-sugar.}}{C_6H_{12}O_6}.$$

There are several varieties of sugar produced by plants, notably the grape-sugar or glucose, and the cane-sugar or sucrose. The grape-sugar is not, as its name might

imply, derived solely from grapes, neither is cane-sugar derived solely from the sugar-cane. The sweetness of honey is due to grape-sugar, while the sugar of the beetroot and the maple-tree is cane-sugar. The liver of an animal body was observed by Bernard to produce grape-sugar, and this has been confirmed by other experimenters. Plants also present to us a lengthy list of acids too numerous to mention here, but the following table gives the composition of some of them :—

Oxalic acid,	contained in	sorrel and green gooseberries	$C_{12}\ H_2\ O_4$
Citric acid	„	lemons	$C_6\ H_8\ O_7$
Tartaric acid	„	unripe grapes . .	$C_4\ H_6\ O_6$
Malic acid	„	apples	$C_4\ H_6\ O_5$

As to the way in which these acids are formed, nothing very certain is at present known. It is very probable, I think, that they are produced by the oxidation of the carbohydrates in the dark ; while the carbohydrates are formed by plants exposed to the light. It is well known that various organic acids may be artificially produced by the oxidation of organic substances ; variations of the extent of oxidation being productive of different acids. Taking this view of the formation of acids in plants, we may suppose that the first compounds formed by assimilation are the carbohydrates, then by partial oxidation these are converted into acids, and then by still further oxidation the result is the highest oxides, namely, carbonic acid and water. Accordingly we must suppose that the sugars of ripening fruits result from the *de*oxidation of the acids, which can be only effected by plenty of sunshine.

Plants are not to be overlooked from a medicinal point of view, for decoctions of various plants have been, from the remotest times, valued as restorers of health; thus sage derives its name from its reputed healing properties. Some of the most poisonous compounds, however, are derived from plants, of which strychnine and prussic acid may be mentioned as poisons of a most virulent type; but, although poisons when injudiciously administered, yet they are frequently used as remedies of different diseases "to which human flesh is heir." Thus we find the Friar in "Romeo and Juliet" remarking, that

> "Within the infant rind of a weak flower
> Poison hath residence, and med'cine power."

With regard to the part which the inorganic or mineral matter (that which remains when a plant is burned) plays in the operations of plant life, nothing very certain can be said. By analysing the ash derived from a plant, we do not in all cases arrive at the information we might require, for, when a plant is burned, the state of combination in which the elements existed in it is changed, so that while the ash contains all the inorganic elements originally present in the plant, it contains them in a different state of combination. The amount of inorganic matter varies in different parts of the same plant.

I have examined the leaves of various trees, with the following results:—

	Inorganic matter per cent.
Ash	11·60
Beech	4·60
Bramble	4·46
Cherry	10·00
Elder	10·33
Walnut	10·00

The ash obtained from wheat and barley gave results as follows in each 100 parts :—

	Wheat.	Barley.
Potash	22.93	13·00
Soda	8·17	8·00
Magnesia	10·84	7·50
Lime	4·26	3·41
Peroxide of iron	0·60	1·73
Sulphuric acid	0·51	0·20
Phosphoric acid	50·37	39·00
Chlorine	0.70	0·07
Silica	1·62	27·09
	100·00	100·00

There is some difference between the above samples. The amounts of silica are especially noticeable, for while in the wheat ash the silica amounts to only about 1½ per cent, in the ash of barley it amounts to as much as 27.

As in the instance of animals, it is requisite to consider the surrounding medium in which they live in order to understand the relation which it bears to their constitution, so in the case of plants we have to examine the soil, so as to satisfy ourselves of the source and nature of their inorganic or mineral constituents.

When it is considered that the soil is the result of the chemical and mechanical alteration of rocks differing very much in composition—by the decomposition, for instance, of granite, limestone, sandstone, and clay-slate (or these in varying proportions) there is no difficulty in understanding why the chemical and physical characters of soils from different localities vary, and hence the greater fertility of land in one district than in another. Some soils, again, are the result of the almost perfect decomposition of these substances, while others are resulting from the less perfect decomposition of them ; this being more or less governed by the length of time which the soil has been under cultivation. In order to promote these chemical changes which render soils more fertile, the mechanical operations of breaking up the soil, and then exposing it freely to the atmosphere and weather, are resorted to. The effect of frost and thaw alternately aids this decomposition very considerably, which renders the previously insoluble compounds more or less soluble, and therefore available as plant-food. For any soil to be fertile it is not only necessary that it should contain certain substances, such as are found in the ash derived from plants, but that they should be present in particular states of combination, for in some instances it is found that although a soil contains the necessary elements, yet vegetation does not flourish upon it, and in this case clearly the union in which they exist is faulty. The most abundant constituent of soils is silica, $Si\ O$, an oxide of the element *silicon*. It is found in a nearly pure state as crystallised

quartz, in many sandstones, and in combination with potash, soda, lime, magnesia, and alumina; and thus combined we find its nutritive value as a constituent of the soil. Plants of one kind always take the same substances from the soil, therefore when one kind of plant is cultivated on the same plot of land for a number of years in succession, the soil is deprived of certain inorganic substances which that kind of plant requires, and if an artificial supply of suitable plant food is not applied to the soil during this cropping, the result is a deterioration of crop, both in regard to quantity and quality, in each succeeding year. This fact has brought about a system of cropping which provides against the undue exhaustion of the land; thus, owing to the large amount of silica, for instance (as a soluble silicate), required for the successful growth of certain crops, the system of cropping provides that plants, which for their growth require large supplies of silica from the soil, shall be preceded and followed by plants which only require a small amount of that substance. But, as in the case of silica, soils may be impoverished by exhausting them of any of the other substances which plants require, by the too frequent application of particular crops, while they may be restored to fertility by either allowing them to remain uncropped and fallow for some time, or by providing an adequate supply of nutritive substances. The first method is indeed Nature's own, and is effective in promoting the natural decay of vegetable substances present in the soil, the decomposition of certain mineral substances, and the absorption and retention of various nutritive gases from the air.

Alumina, *Al O*, is found in great abundance in nature, in combination with silica, as silicate of alumina, which is the chief constituent of clays. Although found only in very minute quantity as a constituent of plants, yet it plays a very important part in their growth, by virtue of its physical properties as a constituent of the soil, one of which is the absorption of ammonia from the air and its capability of holding it as a magazine until required by plants. Soils consisting entirely of either clay or sand would of course be very unproductive, but we never find such existing naturally, clay or sand being always associated with other substances; and according to the proportion and state of combination of these other substances, we find the fertility of the soil dependant. Iron is a constituent of most plants, and in the form of peroxide, $Fe_2 O_3$, it is of value as a constituent of soils, acting similarly to alumina in the absorption of ammonia from the atmosphere. Protoxide of iron, *Fe O*, however, appears to be a prejudicial constituent of the soil. The bluish-green colour of clay subsoils is due generally to protoxide of iron, and it has often been observed that when such subsoils have been opened out and spread over the land vegetation has been very much checked. I observed an instance of the ill effect of clay subsoils containing protoxide of iron in this neighbourhood. The clayey earth was spread over a pasture field, and I am told that on those parts where this was laid, for four or five years after, very little grass grew, very much less than had grown on the same land previously. In order to test the cause of this sterility

I obtained a sample of earth from the spot where that had previously been taken and spread upon the land, and submitted it to analysis. Finding a considerable amount of protoxide of iron in it, I have no doubt that this was the cause of the injurious effect which the clayey earth had upon the land. 100 parts gave the following results :—

Silica	40·24
Alumina	38·62
Protoxide of iron	10·73
Peroxide of iron	0·70
Protoxide of manganese	2·00
Carbonate of lime	5·30
Sulphate of lime	2·05
Undetermined	0·36
	100·00

The inference to be drawn from this is, that if instead of at once applying the fresh subsoil to the land, it had been previously exposed to the air for some time, the *prot*-oxide of iron would have been changed to the state of *per*-oxide, and would have been no longer injurious to the growth of grasses or other plants, but, on the other hand, might have been of advantage when applied to the land ; *per*-oxide of iron having the property, as already stated, of absorbing various nutritious compounds from the atmosphere.

Sulphuric acid in combination with lime, as sulphate of lime $Ca\ SO_4$, is found in plants, and as a constituent of the soil it is of value in fixing the ammonia which falls from the air in the rain, thus accumulating in the

soil a supply of valuable plant-food. Upon this subject Liebig's words are—"The evident influence of gypsum upon the growth of grasses, the striking fertility of a meadow upon which it is strewed, depends only on its fixing in the soil the ammonia of the atmosphere, which would otherwise be volatilised with the water which evaporates. The carbonate of ammonia contained in rain water is decomposed by gypsum in precisely the same manner as in the manufacture of *sal-ammoniac*—carbonate of lime and soluble sulphate of ammonia are formed, and this salt of ammonia possessing no volatility, is consequently retained in the soil. All the gypsum gradually disappears, but its action upon the carbonate of ammonia continues so long as a trace of it exists. The decomposition of gypsum by carbonate of ammonia does not take place instantaneously, but, on the contrary, it proceeds very gradually, and this is the reason why the gypsum acts for several years. Water is absolutely necessary to effect this decomposition of the gypsum, and also to assist in the absorption of the sulphate of ammonia, hence it happens that the influence of gypsum is not observed on dry fields."

Phosphoric acid, in combination with lime and magnesia, is a most important constituent of both plants and animals, and consequently of the soil. The husks of seeds contain a large proportion of the phosphate of magnesia, and in smaller quantity phosphate of potash, as shown by Calvert (*British Association Reports* 1869).

Potash is a very important constituent of plants.

Although soda is very similar in chemical properties, yet when a mixture of potash and soda salts are presented to growing plants, they, in the majority of cases, select the potash and leave the soda. This is very noticeable in the nutrition of marine plants. Sea water consists largely of chloride of sodium, and contains only a very small proportion of chloride of potassium, yet, on examining plants grown in it, we find potash to be a very considerable constituent, while soda is almost absent. The following table shows the amount of potash and soda in the ash derived from different commonly-cultivated plants :—

	Potash.	Soda.
Turnip	41·00	5·20
Potato	60·00	trace.
Clover hay . . .	35·25	1·00
Grain of wheat . .	22·92	8·17
,, barley . .	13·00	8·00

There is a peculiar exception to the rule in the cabbage, in the ash of which there is 20 per cent of soda against only 12·2 of potash.

It was once very naturally considered that in order to find whether a particular soil was suitable for a particular crop, the only thing necessary was to compare the composition of the inorganic or ash constituents of the plant with an analysis of the soil ; but this method, although correct theoretically, is not practically, inasmuch as a soil may contain all the constituents requisite for the crop and in sufficient quantity, yet the amount would be so small as not to be determined

with certainty. Several hundredweights of any substance distributed over an acre of land, for instance, would only afford a very minute quantity in a pound of the soil taken from that acre for analysis, while the deficiency of such a quantity would in some instances cause the perfect sterility of the land. It cannot justly be said, however, that an analysis of a soil is at all times valueless, for the importance must be admitted of knowing at least the chemical *character* of the soil to be worked, which an analysis can alone reveal.

We have already seen that plants not only derive their inorganic or ash constituents from the soil, but that they derive a part of their carbon from the soil also. What relation or importance then does the supply of carbon by the soil bear to the supply of ash constituents? Plants require, in order to flourish most successfully, an amount of food which goes to form the organic portion in direct proportion to that which goes to form the inorganic portion, so that if a soil is exceedingly rich in ash constituents the plants may not be able to avail themselves fully of these without an additional supply of carbonic acid (to supply the carbon) to that which exists in the air, and this it must obtain from the soil. The atmosphere always contains the same amount of carbonic acid, so that the fertility of the soil might in some instances be increased by increasing the gaseous food, and not by increasing the amount of mineral food, in it. This increase in gaseous food in the soil can only be effected by the decay of vegetable substances within it, and this decay can be most rapidly brought about by

the action of the atmosphere and weather. True and successful agriculture does not simply mean getting a sufficient produce from the land, but the improvement of the fertility of it. It will therefore be interesting to ask whether it is likely that the land is being improved or impoverished by the present system of cultivating plants for profit? Where the crop produced is consumed on the farm, then we can trace the direct return of the constituents to the same land, and there is no loss; but, in cases where the produce is exported, it may be otherwise. Liebig says—"The export of grain from a country, unless some article is introduced in compensation, must ultimately tend to exhaust the soil. Some of the spots now desert land in Northern Africa and Asia Minor were anciently fertile. Sicily was the granary of Italy; and the quantity of corn carried off from it by the Romans is probably the chief cause of its present sterility. In this island our commercial system at present has the effect of affording substances which, in their use and decomposition, must enrich the land." The waste which is constantly going on by the present methods of disposing of towns' refuse doubtless has a tendency to exhaust the land, and it is evident, therefore, that a better method of disposing of this refuse is becoming gradually more important. The exportation of crops, and the loss by allowing the drainage from towns to run into the sea comparatively unpurified—or if purified, the fertilising substances not recovered—suggest that the land of this country is being gradually made less valuable; but when we consider the immense

amount of fertilising substances which we derive from other countries, and, in addition, the large quantities of grain imported in return, the previous impression is qualified, and I think we may safely conclude that if the soil is being deteriorated at all, it is occurring very slowly; but I should feel more inclined to look upon it as being to some extent improved, for the constant tillage of the soil necessary in agricultural practice (by which the atmosphere and weather act upon it) opens a magazine of plant food previously existing but not available.

The subject of the chemistry of agriculture is a very wide one, and is being daily enlarged, so that to consider it anything like fully would necessitate the space of a large volume, while it is not necessary for further consideration here.

The grass, which forms the green pasture, or that which, when cut and dried, is gathered together for future use, aptly shows the nutritious nature of the products of the vegetable world. Bread, which can alone be produced by the cultivation of the soil, has, indeed, from that remote period when the soil was first cultivated, been familiar as "the staff of life." As we admire the different shades of colour upon the mountain's breast, do we not also appreciate the deeper lessons which they convey! The colours, while pleasing to the eye, remind us that they are produced by processes which at the same time promote other more important ends; the roots of the plants which bear them are firmly fixed into the breast of the almost per-

pendicular mountain, down which torrents of water flow, and bind the various particles of soil and rock together which would otherwise be washed down to the valleys beneath.

Upon the varied flowers the ingenious members of creation who, *par excellence*, " make hay while the sun shines," feed and bring to their crowded homes mementos of their happy journeyings ; and while we delight to see the beautiful arrangement of these, we prize scarcely less their saccharine produce, accumulated bit by bit from the multitude of flowers on the wayside, or on the mountain's breast. Plants and animals are inseparably connected, so that the words of Longfellow, at the commencement of this chapter, are very applicable to our subject. Professor Pettenkofer, in a paper in the *Contemporary Review* for December last, assigns another value to plants. He says—" I consider the impressions which plants and plantations make upon our minds to be of hygienic value, and further, their influence in the confirmation of the soil, with which health is in many respects connected. It is an old observation, needing no demonstration, that the cheerful and happy man lives, not only an easier, but on the average a more healthy life, than the depressed and morose man. I consider flowers, therefore, in a room, for all to whom they give pleasure, to be one of the enjoyments of life. We cannot live on pleasure alone, but to those who have something to put up with in life, their beloved flowers perform good service." But the effects of the outside world are different on different

minds, and, " as the mind is pitched the eye is pleased ;" while, as Cowper very forcibly says, " familiar with the effect we slight the cause," which is the real beauty in all created things.

CHAPTER III.

Charles Dickens, in the opening chapter of "Oliver Twist," alludes to respiration as a "troublesome practice, but one which custom has rendered necessary to our easy existence."

FOOD, water, and air, are the popular necessaries of life. We may deprive ourselves of the two former for several days, but to be without air for a few minutes causes actual death. Air is therefore the most important body with which we have to do, and its relations to life are most interesting. As the fresh air blowing through a house purifies that house, so the air circulating through our bodies purifies them. If we admit bad, impure air into a house it does not purify it, so if we breathe impure air our bodies are not maintained in perfect health.

When we fail to see an animal breathe (referring of course to the higher forms of life) we conclude at once that it is no longer alive. The air fills our lungs independently of the will, for as the heart beats so do we regularly breathe.

The air passing into and out of our bodies involves something more than a mechanical movement of various parts of them, in fact that is a mere consequence, for the support of life is due to the chemical action which takes place. What are the changes effected in the

chemistry of our bodies by respiration? That which we now know regarding the chemistry of respiration has been derived from observations extending over many years, for it was one of the first subjects which engaged the attention of modern philosophers. We must breathe: how and why, therefore, were questions which naturally presented themselves. In connection with the researches on respiration, I have collected a number of historical points which may be appropriately introduced before detailing the process as we now know it. When we consider that the ancients knew only four "elements" to work upon, and these erroneous ones—not *elements* at all—the reason of the respiratory process being a hidden wonder for ages is not difficult to understand; while it is surprising to note the rapidity with which it was revealed as the fundamental truths of modern chemistry became understood. The most ancient idea as to the object of breathing was, that it was to cool the lungs, and this appears to have been generally accepted until its being a chemical process rather than a mechanical one was suggested in 1648 by Van Helmont. After this fresh theories were numerous, for the point upon which life evidently rested was, of course, very interesting, and a natural desire always prevails to know more about the why and the wherefore of living action. Thus in 1664 a paper was published by Hooke on "artificial respiration," and one by Lower in 1669 "on the changes of colour to be observed in blood by passing through the lungs." Hooke was an assistant to Boyle previous to the publi-

cation of his paper on "artificial respiration," and, as showing that afterwards both Hooke and Boyle were working in the same direction, we find a publication by Boyle in 1670 showing the absolute necessity of air, *i.e.* atmospheric air, for respiration; but I am not able to find anything to show that any particular theory was advanced by Boyle as a reason for the necessity of it. The publications by Hooke, which bore considerably upon ordinary combustion, and the similarity of it to the combustion going on in our bodies, and those by Lower just mentioned, paved the way to the views of Mayhow in 1674, who was at that time a student at Oxford. Here evidently dawned the true light upon the subject of respiration. Mayhow noticed, firstly, that the air we breathe contained a characteristic gas (apparently that which we now call oxygen), and he called it "Spiritus nitroaëreus," because Hooke had previously found that a gas possessing similar properties was evolved from nitre when heated. He noticed, secondly, that by respiration and by combustion the air was deprived of this "peculiar principle," and observed that when animals were kept in a limited amount of air that the volume of the air was diminished. He held that the old idea was wrong, that respiration was not essentially to cool the blood or to promote a perfect mixture of its component parts, but to supply it with the "spiritus nitroaëreus," which was stored up and became productive of muscular action.

Dr. Joseph Black, the first President of the Royal Society, when at the University of Edinburgh in 1754,

first used the chemical balance, and employed it in determining the fact that "quick lime," when exposed to the air, became heavier from the absorption of a gas from the air, which was capable of being expelled from it again by heat. This gas was carbonic acid. Three years later, in investigating into its nature, and the source of it in the atmosphere, he showed that it existed largely in expired air, and that this was evidently a great source from which the atmosphere obtained a supply. In 1771 he published the discovery that air was rendered unfit for respiration and for the promotion of combustion, by having been previously breathed by animals, and that it was purified and made again suitable by the action of living plants. So far so good, but he unfortunately held another opinion in reference to this carbonic acid in the air, which was not so successful, namely, that the carbonic acid of air previously breathed by animals did not proceed from their bodies, but was originally present in atmospheric air, and simply altered in properties by passing through the lungs, by the combination of the air inspired with the supposed phlogiston—a very favourite principle, to which in ancient times almost all unknown and peculiar effects were ascribed. The "phlogistic theory" was first adopted or suggested by Stahl in the year 1697, and was favourably held during the following century. This shows how carefully theories should be drawn; and it has been well said, that "a bad theory is worse than none at all." The theory of phlogiston regarded all combustible bodies as compounds of phlogiston;

this being their characteristic element. On the 1st of August 1774, Priestley discovered and isolated oxygen; and from this discovery we naturally find a new foundation laid for experiment; the theory of phlogiston exploded; and the old views on respiration considerably changed. Subsequently, in the year 1777, Lavoisier distinctly announced the true theory of respiration, and showed that, by breathing, animals abstracted from the air the oxygen, and returned to it carbonic acid. Then, in 1780, along with La Place, he proved that animal heat,—that is, the greater heat of animals above that of the air around, was due to the combination of the carbon and hydrogen of the blood with the oxygen of the air.[1]

Lavoisier, whose history is perhaps the most noteworthy of any philosopher either before or since, was put to death owing to the scientific opinions which he held; and, looking through the histories of science generally, I think we cannot fail to notice that religion has, from very early times, been a damper to the progress of science. Anciently, experiment and reasoning were absolutely prohibited when they related to things concerning life; now, he who ventures a sceptical opinion is on every side decried, and looked upon as the wilful progenitor of that which will break forth to the destruction of religious faith.

There is, probably, no real difference between the true principles of religion and those of science; there

[1] Whenever chemical action occurs, a change of temperature is produced: *generally* an increase.

may be no difference between the creation, as explained in the Scriptures, and as explained by the light of science when read aright, but there is, and apparently has been for an indefinite period, a fear on the part of those whose calling is the teaching of the different religious creeds, that men of science are using their best endeavours to undermine the doctrines which they expound, instead of looking at their actions as prompted by the same feeling as that which called forth in Goethe the oft-quoted expression, "Light, more light." There is, however, one point in reference to the theories promoted by scientific savans, regarding those higher points of Nature with which we can never be absolutely familiar, namely, the too ready acceptance which they frequently receive at the hands of those who have never made the subjects their own particular study. I have seen it mentioned somewhere—I *think* it is a remark of Professor Tyndall's—that "there are only a few minds at the present day able to deal with such abstruse questions as the origin of life;" and, if this were more universally felt and acted upon, there would evidently be less reason for controversy; and although religion has in the past interfered with general science, yet we might naturally expect that now, when much of the haze of superstition has cleared away, there would be none of that opposition which has recently been so rife. Let *us* then leave those "gifted minds" to follow their own course, while we apply ourselves to those beauties of nature in the not less interesting but more tangible

fields which are so bountifully spread before us: taking advice from the words of Pope—

> "Know thyself; presume not God to scan,
> The proper study of mankind is man."

We must *actually believe* nothing without proof. Belief *in science* entails much investigation. "Belief founded upon ignorance is a dangerous kind of belief, and it is a hazardous practice to treat an unproved and unprovable statement as if it were a verified truth. We, however, frequently believe more firmly an uncertain statement than one we can fully prove, and we commonly do so because we wish to believe it, and partly because it cannot be disproved. However true a dogma or hypothesis in science may be in itself, it is *to us* a dead statement, until, by investigation, it is proved to be a living truth. Unprovable beliefs are also often dangerous, because disputes respecting them are a fertile source of strife, injure the moral feelings, and lead to no trustworthy conclusion."[1] Experiment is the foundation for opinion, though theory often suggests experiment. I think it was Roger Bacon who said—"Theory is the General, practice the soldiers;" and we know that to have an efficient army we must have both; but as a bad General is useless, so, as has already been said, a bad theory may be worse than none at all.

The theory of Lavoisier is that now accepted; but in order that we may understand some of the details of respiration as it occurs in the higher animals, and the

[1] Gore, *The Art of Scientific Discovery.* Longmans. 1876.

effect of animal life on the world around, it is necessary that we should examine the blood and the air; the two great agents employed in our continual breathing. We have already seen, Chapter II., that the air continues of one uniform composition by the mutual relations of animal and vegetable life which act upon it, and that it contains in each 100 parts 20·96 of oxygen, 79 of nitrogen, and 0·04 of carbonic acid, with ammonia and other compounds in minute proportions, included in the 79 of nitrogen. With regard to the composition of the blood, a very complete analysis is given by Watts (*Dic. Chem.* vol. i. p. 611), from a number of specimens by Becquerel and Rodier, as follows, in each 1000 parts:—

	Male.	Female.
Water	779·00	791·10
Fibrin	2·20	2·20
Fatty matters	1·60	1·62
Serolin	0·02	0·02
Phosphorised fat	0·49	0·46
Cholestrin	0·09	0·09
Saponified fat	1·00	1·04
Albumen	69·40	70·50
Blood corpuscles	141·10	127·20
Extractive matters and salts	6·80	7·40
Chloride of sodium	3·10	3·90
Other soluble salts	2·50	2·90
Earthy phosphates	0·33	0·35
Iron	0·57	0·54

As well as the solid constituents here mentioned, the blood contains, partly in a state of combination and partly free, oxygen, nitrogen, and carbonic acid gases,

to the extent of from 40 to 50 volumes in each 100 volumes of blood. Arterial blood contains relatively less carbonic acid and more oxygen than venous blood, but the absolute quantity of carbonic acid is greater in both than the quantity of oxygen, while the proportion of nitrogen is in both less than either the oxygen or carbonic acid.[1]

Magnus found the following to be the percentage composition of the gases contained in the blood :—

	Arterial.	Venous.
Nitrogen . . .	14·5	13·1
Carbonic acid . .	62·3	71·6
Oxygen . . .	23·2	15·3
	100·0	100·0

Referring to the analyses of blood by Becquerel and Rodier, just given, we notice blood corpuscles mentioned as existing to the extent of rather over 141 in one case, and over 127 in the other. It is important to notice that these corpuscles contain (indeed, are very largely composed of) a compound called hæmoglobin, which plays, as we shall immediately see, an important part in the chemistry of the respiratory process. It is the compound to which the red colour of blood is due ; an albuminous substance, with which is combined a small quantity of iron. So far, chemists have not given a very reliable formula to this compound, nor is it important for our purpose here that it should be con-

[1] That which has been exposed to the air is called arterial blood, while that which has acted upon the various organs, and is on its way to the lungs to be exposed to the air, is venous blood.

sidered. Remembering that respiration is virtually the oxidation of certain impurities in the blood (the removal of compounds used, and no longer valuable), we ask, where does this oxidation occur? Certainly not, as was once supposed, in the lungs, but in the blood, as it circulates through the body. With the hæmoglobin the oxygen of the air appears to combine *in part*, and is carried in the blood to the various parts of the body, when some of the oxygen thus conveyed combines with the waste materials, which it is necessary should be removed from the system. These waste materials, consisting largely of carbon and hydrogen, the result is, that a corresponding amount of carbonic acid and water is formed, and this carbonic acid, and water as vapour, being conveyed by the venous blood to the lungs, is discharged, and a fresh supply of oxygen acquired from the air, by which the venous blood is changed to arterial blood, and the process perpetuated. This change effected in the blood by passing through the lungs is made evident by the change of colour: after passing through, it is very much darker than it was before. Some difference of opinion has from time to time existed as to the cause of this change of colour, and is thus spoken of by Dr. Kirkes:[1]—"While the scarlet colour of the arterial blood has been supposed by some observers, and for some reasons, to be due to the chemical action of oxygen, and the purple tint of that in the veins to the action of carbonic acid, there are facts which make it seem probable that the cause

[1] Kirkes' *Manual of Physiology*.

was a mechanical one rather than chemical, and that it depended on a difference in the shape of the red corpuscles by which their power of transmitting and reflecting light was altered. Thus carbonic acid was thought to make the blood dark, by causing the red cells to assume a bi-convex outline, and oxygen was supposed to reverse the effect by contracting them, and rendering them bi-concave. We may believe, however, that at least for the present, this vexed question has, by the results of investigations by Professor Stokes and others, been now set at rest. The colouring matter of the blood is capable of existing in two different states of oxidation, and the respective colours of arterial and venous blood are caused by differences in tint between the two varieties—oxidised or scarlet, or de-oxidised or purple." I may just mention that, although in the higher forms of animal life respiration occurs almost entirely by the lungs — only a comparatively slight action going on through the skin—in the lower forms those which are not provided with lungs, or as fishes with "gills," respire through their outer covering the oxygen of the air, which furthers the same oxidising changes, as we have already noticed. It may, however, be remarked that the skin in the higher forms of life has most important functions to perform, and the old proverbs with regard to cleanliness are evidently well founded. Substances are evolved from the body in the perspiration, which, for health, it is necessary should be removed, and the check of perspiration is a frequent and familiar cause of various ailments.

We are constantly perspiring, although oftentimes we are not aware of it. It may be always concluded that anything constantly going on independent of the will is necessary for our existence, and that anything which aids such action is of some service, and *vice versa.*

The changes effected in the air by being breathed are these:—

1. The oxygen is lessened.
2. The carbonic acid is increased.
3. The watery vapour is increased.
4. The ammonia is increased.
5. The organic matter is increased.
6. The nitrogen is proportionately lessened.

1. The normal amount of oxygen present in the air around is nearly 21 volumes in each 100, while after being breathed it amounts to only about 16—thus there is a diminution of 5 volumes in each 100 volumes of air. The same air cannot be rebreathed with impunity until it has mingled with the outside air, and thus become diluted and purified.

2. As has already been explained, the amount of carbonic acid in the air around amounts to only about 4 parts in each 10,000. The average amount in expired air is, however, over 10 times as much—namely, 43 parts in each 10,000 of the air. The increase in the amount of carbonic acid in the air by being breathed may be made evident by a very simple experiment. When carbonic acid gas is passed into clear lime-water (a solution of lime) it combines with the lime to form

carbonate of lime, which, being insoluble, produces an opacity or cloudiness in the solution. If ordinary atmospheric air be passed similarly through lime-water, the lime-water remains clear, because the amount of carbonic acid present is very small; but if, instead of passing through it atmospheric air, we passed air from the lungs, the lime-water would at once be rendered turbid, thus clearly showing the presence of a large quantity of carbonic acid in expired air.

The precise amount of carbon eliminated from the system as carbonic acid, by respiration, is liable to vary in accordance with different surrounding conditions, such as variation in temperature, purity of the air, and exercise. Valentin and Brunner's experiments, published in 1844, show that under ordinary conditions the amount of carbonic acid gas exhaled from the lungs in an hour by a healthy man amounts to 1346 cubic inches, or about 636 grains by weight, which is equal to 173 grains of carbon, so that broadly speaking the amount of carbon discharged from our lungs during 24 hours is more than half a pound. Heat, as an external influence, appears to cause, within certain limits, a diminution in the amount of carbonic acid exhaled; thus Vieorordt, whose investigations have gone so far to extend our knowledge of the details of physiological phenomena, asserts that between the temperature 38° and 75° of Fahrenheit's scale (that commonly used in England) each rise of 10° in temperature causes a diminution of nearly two cubic inches in the amount of carbonic acid exhaled per minute. As to the purity of the atmosphere on the

amount exhaled, it is found that when the carbonic acid is great in the air breathed, the amount of it exhaled is proportionately less. Many years ago experiments were made by Allen upon this subject, which showed that while 32 cubic inches were exhaled when air was breathed in its natural state of purity, not quite 10 were exhaled when air which had been previously repeatedly breathed was inhaled (*Phil. Trans.* 1809).

In reference to the effect of carbonic acid on health, some experiments by Dr. Angus Smith, communicated to the Literary and Philosophical Society of Manchester in 1865, "On some Physiological Effects of Carbonic Acid and Ventilation," are very interesting. The details are too minute to mention here, but the conclusions are important. He shows that the breathings become rapid as the carbonic acid in the air increases. He used a lead chamber in which to conduct the experiments, and says—"In one experiment the breathing was changed from 16 inspirations per minute to 22, the pulse fell from 76 to 55, whilst it was so weak that it was difficult to find." Again—"I shall not pretend to say how health is affected further than this, that a change is observed in the respiration and the pulse. The conclusion is, that in the air containing an increased amount of carbonic acid, this gas alone, even without the other hurtful ingredients, such as organic matter, begins to poison, and men exposed to it are really gasping for breath without knowing it. All the other hurtful ingredients contribute their powerful aid."

The quicker we walk the oftener we breathe, thus

the influence of exercise on breathing and on the amount of carbonic acid discharged from the lungs is evident. Experiments by the late Dr. Edward Smith gave the following results:—

	Carbonic Acid exhaled per minute.
In profound sleep, lying posture .	4·50 grains.
In light sleep	4·99 „
Walking at 2 miles per hour . .	18·10 „
„ 3 „ . .	25·83 „
Tread-wheel, ascending 28·15 feet per minute	43.36 „

The same experimenter shows that the respiratory action varies to some extent during different seasons of the year. In June and till September the proportion of carbonic acid exhaled was found to lessen, while in October and the winter months it increased.

Having seen that the temperature of the surrounding air,[1] the purity of it, and indeed the season of the year, each cause variations in the extent to which the respiratory functions act, the effect of food upon the same remains to be considered. Certain kinds of food influence the respiratory changes more than others. Those consisting largely of carbon, such as oils and starches, cause more carbonic acid to be expired than the nitrogenous substances, such as the flesh of animals. Dr. Edward Smith says—" 1½ ounce of sugar dissolved in water gave a maximum increase in the carbonic acid evolved of 2·18 grains per minute, and an increase in the air inspired of 111 cubic inches per minute." No

[1] The barometric pressure must also influence respiration.

doubt the various fats which are even more carbonaceous than sugar would affect the process even more markedly. As regards the effect of alcohol on respiration, the same writer suggests a difference in the effect produced by different spirits, namely, that while whisky, gin, and brandy, lessen the respiratory changes, the opposite is the case with rum, sherry, and especially pure alcohol. No doubt the influence of alcohol on the respiratory process is different in different individuals. Such is at all events the case in reference to the beatings of the pulse, and unquestionably the circulation of the blood in our bodies is closely connected with our respiration. From my own experiments, I find the effect of alcohol on persons of general nervous temperament to be a reduction in the beatings of the pulse, while, on the other hand, those *not* nervous, but strong, experience an increase in these pulsations by the use of alcohol. In several instances this was very marked.

It is usually much more easy to comprehend a fact than to assign a reason for it, but a probable reason for this difference in the action of alcohol on persons possessing different degrees of nervous stability may, I think, be as follows :—A person of nervous temperament has normally an irregular and rapid pulse, while a person who is of the opposite temperament has a firmer and considerably slower pulse. The natural effect of alcohol, within certain limits, upon the former, would then be to give confidence and to subdue nervous irritation, and therefore diminish the number of beatings of the pulse, while in the latter, a steady and slow pulse

being a natural accompaniment, the effect of alcohol would be to produce more or less excitement, with a corresponding increase in the pulsations.

3. What we speak of as a close day is due very often to the air around being saturated with watery vapour, and thus preventing the skin from freely perspiring as is natural. As in the consideration of the last constituent, so in this, we are able to prove by a very simple experiment, the increased amount of watery vapour in the air exhaled from the lungs as compared with that inhaled. We have simply to breathe upon a cool surface, against a pane of glass in the window, for instance, when the watery vapour is at once condensed and runs down the glass as water. Observe something further, however,—that this condensed vapour has often an unpleasant smell ; it is due to the presence of organic matter to be presently described.

The amount of water given off from our bodies in this way is subject to some variation, of course as the respiratory changes are affected by temperature of the body and of the external air, exercise, atmospheric pressure, and dampness. It has been calculated by Dr. Chaumont that 2000 persons give off from the lungs, and by perspiration, as much as seventeen gallons of water in two hours, in the form of vapour, and as much carbonic acid as would be produced by burning one hundredweight of coal. The importance of complete ventilation in public rooms here strikes us. In rooms in which ventilation is not properly effected, a natural performance of our experiment goes on. The moisture

given off by persons breathing in the room is condensed upon the walls, and the organic matter along with it, which is absorbed and retained by the wall-paper, thus forming an impurity lasting for some time and becoming offensive even to the smell.

4. The amount of ammonia present in the atmosphere is, in proportion to the other constituents, small, and indeed, in the air after being breathed, the proportion is only slightly increased, though distinctly detected by chemical analysis. Taking the atmosphere as a whole, extending as it does to a height of at least forty-five miles, and to an almost inconceivable distance on each side of us, the quantity of ammonia contained in it is an important one,—aiding, as we have seen, so considerably in the growth of plants. To the chemistry of animal respiration, ammonia does not, however, bear such important relations.

5. In mentioning the increase of the amount of watery vapour in the air by being breathed, it was also observed that organic matter was often to be detected in the condensed moisture by the unpleasant smell which it affords. Along with carbonic acid, this organic matter is the product of respiration, which it is important should be removed from the air of rooms by proper ventilation; or, in other words, it is this organic contamination, and the carbonic acid, which necessitates a change of the air in rooms, in order that the impure air may be purified by mixing with the atmosphere, in which chemical changes are being effected on a magnificent scale. It has been observed that a determination

of the amount of carbonic acid in the air gives a good idea of the amount of organic matter also present, since these compounds appear to exist in relation to each other. The direct determination of the organic matter in the air is a very difficult one, while the determination of carbonic acid is very simple.

Those already described are the important changes effected in the air by animal respiration, but it is important to notice more fully the products of respiration, in order that we may understand the value and effect of proper ventilation more thoroughly. The carbonic acid and the organic matter are the important ones.

Dr. Ransome, in a paper on the amount of organic matter in the human breath, in health and disease, says —"In diseased states of the system there is much greater variation in the amount and kind of organic matter given off than in health;" and remarks—"We cannot doubt that much of the disease which arises as a consequence of over crowding, finds some of its sustenance in the impure vapours arising from the lungs and the general surface of the body."[1] Observe, "*some of its sustenance.*" This does not only mean that diseases are produced by these foul emanations, but that they are sustained, encouraged, or spread.

Besides instances of actual suffocation by a number of people being confined together, notably, one in which 73 out of 200 emigrants were suffocated on board an emigrant vessel some years ago, we are frequently told that by the breathing of impure air,

[1] Manchester Lit. and Phil. Soc., 1870.

diseases are induced from which deaths are occurring daily. The effect of air largely polluted with carbonic acid is more *rapid* than the effect of air polluted by organic matter, though the organic air-contamination, when breathed for any lengthened period, is equally as injurious as the contamination by carbonic acid. The organic matter is at the same time more treacherous, and is usually accompanied by a serious quantity of carbonic acid. The effects of carbonic acid on combustion and upon respiration bear much relation to each other. We have previously seen that, as by our breathing, when any substance containing carbon is burnt in the air, carbonic acid is produced. The effect of the products of combustion upon combustion are well shown by the following simple experiment:—Take a candle, light it and keep it covered by a glass jar, or by any other means in a limited amount of air; in a short time it will begin to burn dimly, then produce a smoky flame, and finally be extinguished, owing to its own combustion having taking up the oxygen of the air and replaced carbonic acid. So, if we were kept in a closed room into which no fresh air was admitted we should begin to feel ill, and, if we did not take the hint, ultimately die. Human nature is fortunately usually roused before this occurs, but often not sufficiently early, for the uncomfortable feeling often experienced in rooms in which ventilation is imperfect doubtless is frequently the germ of future disease and decay. A "close" room is too familiar to every one. The unpleasant feeling which we find on entering such

a room from the open air[1] is clearly not due to the ordinary constituents of the air, but to the organic emanations from the bodies of persons already occupying it.

It may be mentioned, as showing the dangerous character of air polluted by organic matter, that while air mixed with one fiftieth of its volume of carbonic acid alone may be breathed (though of course not without increasing danger), the same amount of air mixed with one quarter of that amount of carbonic acid, but accompanied by the usual organic impurities, proves much more poisonous. The late Dr. Parkes, Professor of Hygiene in the Army Medical School, Netley, furnishes in his *Practical Hygiene* statistics which show in a very striking manner the effects of bad air. They may be briefly stated as follows :—In the years 1834 to 1847, in the badly ventilated prison of the Leopoldstadt in Vienna, the deaths per 1000 prisoners were 86, and, out of these deaths, 51·4 were due to consumption, while, on the other hand, in the House of Correction, in the same city, which was well ventilated, the deaths per 1000 were only 14, of which 7·9 were due to consumption ; from this it is evident that 43½ per 1000 were distinctly attributable to bad air. It is not only in regard to human beings that foul air proves injurious, but to all other domesticated animals.

Dr. Angus Smith, who has considered very fully the subject of air and ventilation, publishes amongst the rest

[1] Observe those already occupying it frequently do not perceive the "closeness" of the air.

the following table, showing the amount of carbonic acid in various close places in London.

	Per cent per volume.
Chancery Court, closed doors, 7 feet from ground	0·193
Same, 3 feet from ground	0·203
Chancery Court, doors wide open, 4 feet from ground, 11.40 a.m.	0·0507
Same, 12.40 p.m., 5 feet from ground	0·045
Strand Theatre, gallery, 10 p.m.	0·111
Surrey Theatre, boxes, 7.12 p.m.	0·218
Olympic, 11.30 p.m.	0·0817
Same, 55.11 p.m	0·1014
Victoria Theatre, boxes, 10 p.m.	0·126
Haymarket Theatre, 11.30 p.m.	0·0757
Queen's Ward, St. Thomas's Hospital, 3.25 p.m.	0·040
Edward's Ward, St. Thomas's Hospital, 3.30 p.m.	0·052
Pavilion, 10.11 p.m. (Whitechapel)	0·152
City of London Theatre, pit, 11.15 p.m.	0·252
Standard Theatre, pit, 11 p.m.	0·320

Remembering the percentage of carbonic acid in fresh country air to be not more than 0·04, but generally rather less, and comparing the above, we see the difference as regards carbonic acid between good country air and that of the London Law Courts and Theatres. Thus the air of the Chancery Court contained about five times as much as good country air; that of the Strand Theatre eight; City of London Theatre over six; and the Pavilion nearly four. Since the organic matter usually bears distinct relations to the carbonic

acid, the above figures may apply to that contamination also, and we have at once an idea of the unhealthiness of continued habitation in such places. In order to counteract these circumstances, it is necessary that the air should be constantly changing; and to promote this in dwelling-houses (although not sufficient), the opening of windows, top and bottom, should evidently not be overlooked. Air may not be suitable for respiration, although not foul in the sense in which we have just used it, namely, with regard to carbonic acid and organic matter. The purest country air, when it is damp from much evaporation from boggy lands, is not suitable for constant respiration. Before the Parliamentary Committee appointed to consider the scheme for the supply of water from Thirlmere to Manchester (1878), it was shown that a very large death-rate in proportion to number of inhabitants existed in one of the most picturesque and remote valleys of Cumberland (the vale of St. John, near Keswick). The fatal disease was consumption, and attributed, not to air polluted by artificial means, since in reality no artificial source of pollution, as in our manufacturing towns, exists there, but to the dampness of the air, caused by badly-drained swampy lands. I think, however, it a question whether something more than dampness might not be produced by this undrained boggy land, even organisms resulting from, or promoted rather by, the gradual decay of the vegetable substances in the land. Many fevers in foreign countries are attributed, again, to badly-drained or boggy lands, in which there is a continual

decomposition of vegetation. Although much stress is usually laid on the air of towns as being impure, and very little said about the air in country places being bad, yet it may be often found in country villages that the houses are surrounded by putrefying masses of dead animal and vegetable substances, and that on many an evening, when the air is warm and still, the odour from these is painfully evident some distance from the immediate source. Although in most country districts "Sanitary Authorities" are established, yet many of these sources of serious air-pollution still remain, and farmers are not yet deprived of what they consider one of their greatest treasures, a "sump," which means a receptacle (usually open) for all the refuse of the yard, which in due season is applied to the land, with the no doubt correct idea of its immense value in the growth of various crops. But although valuable in this respect, the collection must evidently be very detrimental to health, owing to the putrid gases with which it contaminates the air around.

While a body is alive its temperature is considerably higher than that of the surrounding air ; after it dies it assumes the same temperature. This higher temperature of our bodies above that of the air is called *animal heat*, and is due to the living action, or chemical action constantly going on. Plants also possess a degree of heat higher than the air by which they are surrounded, owing to the chemical action which occurs in them ; and as the greater or less degree of heat depends upon the greater or less amount of chemical

action, the difference in temperature between plants and animals is in direct proportion to the chemical action taking place in each. The average temperature of the human body is 100° Fahr. In cold weather, when the cool atmosphere deprives our bodies of their heat, which is the true reason of our feeling cold, more chemical action or respiration is necessary to keep up the heat of our bodies without an increase of clothing, and therefore there must be an extra waste of tissue going on, with a proportionate necessity for an extra amount of food being taken for its repair.

The hydrocarbons and carbohydrates (starches, sugars, and fats) are, it will be remembered, the class of foods which are of most value in keeping up animal heat. Accordingly, in cold climates, the natives are in the habit of using large quantities of oil and fat as food. Thus we are told that an ordinary relish for the Esquimaux is about 20 lbs. of flesh and oil! However absurd this might appear in the very different conditions which we enjoy, there is nothing remarkable when we consider the intense cold which they are called upon to bear, and the vital functions necessary to be kept up to counteract its effects.

To conclude, the objects of respiration are—firstly, to remove from the body various matters resulting from the working of it which causes the disarrangement, chemically speaking, of various parts; and, secondly, to keep up the necessary warmth most favourable for the performance of the functions of life. The result of it is the pollution of the atmosphere with

noxious vapours; and the extent of this pollution is evidently enormous, when we consider the innumerable animals which inhabit the earth, each contributing to this pollution. The atmosphere, however, as a whole, being self-purifying, the deleterious gases discharged from our bodies are rendered innocuous, or, in popular language, destroyed; for we have, in the enormous laboratory of the sky, chemical changes occurring on an immense scale, while a large amount of air purification is effected by living plants.

CHAPTER IV.

"The worth of a State, in the long run, is the worth of the individuals composing it." J. S. MILL.

DR. LONSDALE, in one of his *Cumberland Worthies*, remarks that "a good pulse and a good digestion constitute nine-tenths of the groundwork of a man's success in the world of competition. How great soever the mental gifts may be in an individual, the exercise of them remains more or less in abeyance under the dark clouds of dyspepsia. No puny-framed person has reached the higher honours of statesmanship, and no bilious phlegmatic lawyer, as far as I know, has attained the woolsack. The men of eminence who have figured in history, be they soldiers, philosophers, physicists, or others, have been strong-stomached, or, as Paley, who was a true example of the kind, used to say, good trencher men."

The outcome of proper digestion is the actual conversion of our daily bread into flesh, muscles, bones, and sinews; and when it is considered that this can only be effected by the co-operation of a number of different processes, each process having an essential part to perform, we may not wonder at the liability of this faculty to become impaired. No doubt a good digestion goes very far to promote that great desidera-

tum, "a sound mind in a sound body," for writers on health invariably dwell upon the importance of a cheerful temperament, and show that a good digestion is a great aid to it.

Before examining the fluids which operate, and the way in which they operate, in the digestive processes, it will be well for us to consider the various substances which they are called upon to digest. These are all included under the comprehensive word *Food*, and are necessarily substances which, when digested, renew some organ or maintain some vital process, such as respiration. Our bodies are continually changing, and as the wheel of life in going round wears away some of the machinery which it turns, food must be taken for its repair. The renewing substance must be of precisely the same nature as that which it is to renew, so that bone can only be renewed by the use of food containing the compounds of which bone is formed ; and flesh, by the compounds of which it is composed, and preferably by those substances which in affording these are most easily digested. To be a food it is not necessary that it should supply in itself all the different kinds of material which a living body requires, for then one variety of food would be sufficient ; but it is requisite that it should provide some of the materials necessary, so that by a combination of different foods the whole of the necessary materials may be provided.

We naturally look upon a food as being something solid, but this is not strictly correct, since air and water are in reality peculiar forms of food, though naturally

supplied to us. We are strangely apt to consider every article as unsatisfactory which is not to be paid for, as something for which no thanks are due, or as something of little value. Accordingly, the country villager who has a bountiful supply of good water at his disposal does not appreciate its full value till he experiences the rates of a town for its supply. We may therefore say with the poet, that—

> ". . . What we have we prize not to the worth
> While we enjoy it; but being lacked and lost,
> Why then we rack the value; then we find
> The virtue which possession would not show us
> While it was ours."

Certain kinds of food aid certain physiological processes more than others, while many different foods answer the same purpose, so that we are fortunately able to change the food to obtain different flavours, as we may desire, without interfering with the proper nutrition of our bodies as a result. We have, for instance, in the vegetable world, the same nutritive substances that the animal world affords, and are therefore capable of living either upon vegetable foods alone, or entirely upon animal foods, though a mixture of both is by far the most desirable. One point should be mentioned, namely, that animal foods are usually found, when properly cooked, more digestible than vegetable foods. Although beef and mutton are materials of precisely the same nature, yet epicures have professed to detect a difference in their effects, and it is said that Kean, the actor, changed the kind of meat he

ate according to the part he was about to perform, and selected pork for tyrants, beef for murderers, and mutton for lovers! These distinctions, although possibly resulting from satisfactory practical application, are beyond the powers of further reason; yet, fortunately, when compared with the assertions of the epicurean philosophers of old, their ridiculous nature may be somewhat lightened by the comparison, and the mutton at least tried with the view already expressed; for these ancient philosophers did not hesitate to say at what particular part of a stream a certain fish was caught, or upon which leg a partridge had slept the night before it was killed!

The deprivation of food causes a gradual waste of the body, a gradual loss of animal heat, and finally actual death, so that hunger has been associated by Carlyle with the policeman as a mover of society; and truly, however remiss the policeman may be in doing his duty, hunger will not show the bad example so long as the body is healthy.

Food may be considered as in the divisions previously made, namely the hydrocarbons and carbohydrates, which, on account of their aiding largely in the respiratory process, are sometimes called "heat-givers," and the nitrogenous substances commonly called "flesh-formers." These popular distinctions, although conveying a good idea of their characters, are not absolutely correct, since the albuminous or nitrogenous substances used alone would fail without the carbohydrates or hydrocarbons to form flesh, while these would be equally

wanting without the nitrogenous bodies. There must be in food, then, in order to effectually nourish us, a due proportion, to be considered hereafter, of both these classes of substances. The first class including the starches, sugars, and fats, as previously described (Chapter I.), the latter including albumen, fibrin, casein, and gluten, as previously mentioned. These substances do not exist in food in a pure state, that is, they are associated with various inorganic compounds, some of which go to form bone, others aid digestion, so that their presence may be looked upon as necessary.

In order to test the nutritive value of the carbohydrates when administered as food alone, Gmelin undertook a number of experiments which show beyond doubt their inability to support life for any lengthened period.

Different geese were fed, one with gum and water, another with sugar and water, and another with starch and water. In each instance there was a gradual loss of weight, and, as a result, the one fed with gum died on the sixteenth day of such treatment, that fed with sugar on the twenty-second, and that fed with starch on the twenty-fourth. Although the nitrogenous substances (albumen, fibrin, etc.) may support life for a longer period, yet they must ultimately fail. If we look at the composition of milk, which is a natural food, we shall find there a due proportion of both the carbohydrates and the nitrogenous bodies, thus :—

	Woman.	Cow.	Goat.	Ass.
Water	88·6	87·4	82·0	90·5
Fats (hydrocarbons) .	2·6	4·0	4·5	1·4
Sugar (carbohydrate) .	4·0	5·0	4·5	6·4
Casein (nitrogenous), and inorganic salts . .	3·9	3·6	9·0	1·7

Bread also is a mixture of these substances, and it is a matter of fact, that of all diets which may be continued alone, the bread and milk is capable of sustaining life most effectually. By examining such natural foods, noticing the proportions which the constituents of them bear to each other, we are aiming in the right way to gain a true knowledge of the principles of nutrition, for here nature is, as in other cases, her own interpreter. We have to put questions to nature in order to extend our knowledge on any subject, and, when these are properly asked, that is, when they bear properly upon the subject, the answers are always clearly and rightly given, and each step attained in this way is a step higher and on a sure foundation. Thus Longfellow wrote of Agassiz, who devoted his lifetime to the study and revelation of those boundless laws and treasures, which govern the universe :—

> "He wandered away and away,
> With Nature, the dear old nurse,
> Who sang to him night and day
> The rhymes of the universe.
> For whenever the way seemed long,
> Or his heart began to fail,
> Nature sang a more wonderful song,
> Or told a more marvellous tale."

By the process of respiration in animals, there is, as we have seen, a loss occasioned of the substance of their bodies. The purpose of digestion is the repair of it. Any increase of weight of an animal is due to the appropriation of substances in greater quantity than is required for the actual repair of the waste. Such increase of weight only takes place for a limited period in the existence of all animals; a time follows, usually comparatively lengthy, when the changes are balanced—when the waste and repair are equal—so that the body remains of about the same weight; and finally, a period when the circumstances are reversed, when the waste is greater than the repair, when the body gradually loses weight. There are therefore in the ordinary complete life of a human being three ages. From this view of the waste and repair of the substance of our bodies, it has been calculated that they are thoroughly changed as regards their chemical parts in each seven years, that is, that not one of the particles of which we are now composed will be present in our bodies seven years hence, or that we do not now contain one of the same chemical particles we did seven years ago. It is, however, interesting to notice, that although the brain, like the other organs, is changed, the knowledge then possessed remains, and that while there is a constant change of material going on in our bodies, there is not necessarily a change of mind.

> "All substance must have limits, who may trace
> The limits of the mind!"

An animal's growth is limited, but not that of plants, for various trees have evidently grown for hundreds of years, and each year added largely to their size ; in fact, plants enlarge their structures up to the time of actual death, and while one part is absolutely dead and decayed, another part may fulfil its various functions as perfectly as before. This latter is of course to a certain extent the case with animals, but not so perfectly as in the instance of plants. An animal may have a portion of its structure severed from the rest of its body, which as before may perform all its functions perfectly, though a natural decay of any particular part affects the whole much more seriously than the natural decay of a part of a vegetable structure affects the whole of it. From what has been said with reference to three ages in the lives of animals, it follows that the food for animals, after a certain time, is not required for the enlargement of their structures, but simply for their maintenance,—to compensate for the muscular energy expended, or work done, as, in proportion to the amount of energy expended, we have loss of tissue, which the digestion and assimilation of food can alone make good. Food, therefore, which would be requisite, in regard to amount, for an active individual would be more than necessary, and consequently injurious to one of less activity. The nature of food and its relation to work may be understood by the following explanation :—All substances united together chemically are held together by force or energy. The force or energy with which they are held together is latent, but when the substances

are torn asunder, the energy is also separated from the material substances, and manifests itself as heat or light, and in some instances both, and capable of being converted into motion. We have an everyday instance of this in the railway train, which is driven by the energy given out from the coal, by which its particles were held together. Chemical compounds (food for instance), then, consist of material plus force: so do our bodies. In our bodies the force is latent, but capable of being developed as we desire, while the materials remaining after the force has been separated are cast from the body as useless by the secretions, or in the products of respiration, though somewhat changed as regards their chemical nature. It is necessary, in order that this process may be kept up, that something enters into the body which may supply it with the material and force which the peculiar function of living action is to separate as required, and this we call food. The condition of our bodies at any particular time will depend, then, upon the relative extent to which these conditions exist, namely, the total material plus force, the force expended or work done, and the consequent waste of material. But while we say that the will is capable of separating, as above, the *materials* from the *force* which holds them together, and of liberating the latter, yet chemical action is the real operator in this transformation; and in the removal of the waste material from the body, heat is generated by the chemical action involved, as described in the last chapter.

With regard to the amount of food which can be properly appropriated, it is found that there is a variation in different cases, according to age and activity, but the continued over-supply of food is certain in all cases to have injurious effects: disordering the digestive faculty by stimulating to undue activity, and also disordering the secreting organs by causing them more than a natural amount of work, which cannot be accomplished so thoroughly. It might appear reasonable to suppose that the more food consumed the more flesh would be formed and the larger the various tissues would become—we should then all be giants!—but actual experiment shows that we can only assimilate a limited amount of food, and the excess over this amount is cast away without conferring any benefit. Of the various tissues, only one is actually increased by what we may call an over-supply of food (the adipose or fatty tissue), and indeed this must be of limited duration. The accumulation of fat in the organism appears to be only valuable as forming a supply of that which is most appropriate for keeping up the heat of the body in cold weather, and when there may be a scarcity of food. It is noticed that when an animal is undergoing starvation the heat-producing process (respiration) is kept up chiefly by the accumulated fat, which is thus gradually consumed, and when completely used up the temperature of the body gradually falls, until living action can no longer be sustained. Of course all the tissues of the body suffer a loss by the deprivation of food, but the fatty tissue suffers the most.

M. Chossat made a number of experiments upon pigeons by depriving them of food. He found the various parts to undergo diminution as follows :—

	Per Cent.
Fat	93·3
Blood	75·0
Spleen	71·4
Pancreas	64·1
Liver	52·0
Heart	44·8
Intestines	42·4
Muscles of locomotion	42·3
Muscular coat of stomach	39·7
Skin	33·3
Kidneys	31·9
Respiratory apparatus (lungs)	22·2
Osseous system (bone)	16·7
Eyes	10·0
Nervous system	1·9

Thus the nervous system remains almost unaffected by starvation. Cold may be said to be constantly at war with life, but those animals which are most largely exposed to cold have a tendency to accumulate in the autumn a quantity of fat, which proves effectual in counteracting the cold of winter. The production of fat in the animal organism has been considered in Chapter I., and shown to be largely due to the carbohydrates. But, although supplied with the most eligible food, many animals fail to appropriate fat—a difference frequently being noticed in animals of the same species. These remarks apply to human beings as fully as to the lower animals, and there is also some difficulty in

deciding as to the amount of food absolutely required for general work. Dr. Dalton gave the following as showing what he considered to be the amount of food necessary per day for a healthy man taking free exercise in the open air—"Meat, 16 ounces; bread, 19; butter or fat, $3\frac{1}{2}$; and water, 52 fluid ounces." It has been previously remarked that a due mixture of carbon and nitrogen is necessary to the successful nutrition of our bodies, and as no one kind of food at present known is capable of supplying these elements in their proper proportions and in sufficient quantity, it is necessary to have a mixture of different foods in order to supply just the right amount of carbon and the right amount of nitrogen. But apart from the purely chemical view of such a mixture of foods, the taste is not satisfied without a change of diet, and indeed the digestive functions are deranged by the continued digestion of a particular food. Dr. Carpenter says[1]—"It appears from enquiries into the amount of different kinds of food consumed by the ordinary labouring population, that a daily average of about 5000 grains of carbon and 216 grains of nitrogen is absolutely required to maintain the system in health: a reduction of one-eighth being attended with decided diminution of vigour. A well-fed man consumes about 300 grains of nitrogen per day; and since, according to Payen, 1000 grains of bread contain (in round numbers) 300 grains of carbon and 10 grains of nitrogen, a man living on bread alone must eat 30,000 grains (or nearly 4 lbs.)

[1] *Manual of Physiology*, p. 326.

of it in order to obtain 300 grains of nitrogen, whilst, on the other hand, he need only eat 16,666 grains (or but little more than half the quantity) to obtain 5000 grains of carbon. Hence it is obviously economical to add to a bread diet a small quantity of flesh, cheese, or other highly nitrogenous food. Again, 1000 grains of meat contain, in round numbers, 100 grains of carbon and 30 grains of nitrogen; hence a man living upon meat alone must consume 50,000 grains (or more than 7 lbs.) to obtain 5000 grains of carbon, whilst he need only eat 10,000 grains (or one-fifth of that quantity) to obtain 300 grains of nitrogen. Hence when meat is largely used it should be combined with a considerable proportion of amylaceous[1] substances. From this we see that the proportions in which the carbon and nitrogen in our food should exist are about as 23 to 1. Dr. Carpenter also tells us that "about 2 lbs. of bread and $\frac{3}{4}$ lb. of meat will afford adequate sustenance to a healthy man under all ordinary circumstances of exertion and temperature, and this is more than is required by such as lead sedentary lives, and are but little exposed to cold." These remarks are intended to apply to those who have attained what we have previously called the second stage of life—that period when the waste and repair are balanced—as in the latter part of the first stage of life—the period of growth and hardening of the muscles—more food may perhaps, with due exercise, be necessary. At this period

[1] Amylaceous: of the nature of starch. Potatoes and other vegetable roots consist largely of starch.

the object is to have sufficient exercise to cause a rapid waste, and then food sufficient for a rapid repair of the various parts of the body. The numbers given by Dr. Carpenter are the result of investigations of numerous actual dietaries, and are therefore perhaps more reliable than those by Dr. Dalton formed from experiments upon himself exclusively. Certainly the 16 ounces of animal food mentioned by the latter is large.

Dr. Lyon Playfair has constructed the following table, showing the amount of carbonaceous and nitrogenous food necessary according to work done :—

	Nitrogenous.		Carbonaceous.
For subsistence only .	2·0 ounces	+	13·3 ounces.
For quietude . .	2·5 ,,	+	14·5 ,,
For moderate exercise .	4·2 ,,	+	23·2 ,,
For active labour . .	5·5 ,,	+	26·3 ,,
For hard work . .	6·5 ,,	+	26·3 ,,

Comparing these figures together, we notice that as the amount of work increases, the nitrogenous food necessary increases more than the carbonaceous ; thus, between "active labour" and "hard work," we notice an increase of 1 ounce of nitrogenous food, while the carbonaceous food necessary remains the same. It may be observed that an increase of 1 ounce of nitrogenous food is considerable, when "for subsistence only" (the first item in the table) the proportion of nitrogenous food is only 2 ounces to over 13 of carbonaceous.[1]

[1] Nitrogenous food means food containing nitrogen ; of course not nitrogen itself.

The fact of an increase of nitrogenous food being necessary when hard work is performed, suggests to us that a loss of nitrogen must take place from the body in proportion to work done. The increase of nitrogen discharged from the body is to be found chiefly in the fluid excretion in the form of a compound called urea. Accordingly, by determining the increase of nitrogen evacuated as urea, we have an index of the amount of work done.

But, passing from the nature of food to the digestion of it, we here enter upon the consideration of a series of complicated chemical processes upon which the health of all depends. Shakspeare, therefore, writes with expression :—

> "Now, good digestion wait on appetite,
> And health on both."

When food is taken into the mouth, it is, or ought to be, properly masticated, by which it may not only be reduced to small pieces, but thoroughly mixed with the saliva which is secreted by glands situated at the back of and beneath the tongue. There are several of them, and the saliva from each varies *slightly* in composition. It is not the simple mincing of the food which is important, but the mixing of it with the saliva, by which various chemical changes are effected ; for the chemistry of digestion tells us that a very large proportion of the food we take should be digested by the saliva alone, and thus brought into the immediate condition in which it is capable of supporting the various organs of the body. Of course, the saliva is also of advantage,

mechanically, in aiding the easy disintegration of the various foods; and the amount of saliva secreted by the glands is in direct proportion to the hardness and dryness of the foods. Food improperly masticated, when digested at all, is digested with difficulty, because the various fluids to which it is subsequently exposed cannot act upon it so easily; and clearly this must aid in the derangement of the digestive organs. Saliva varies somewhat in the proportion in which its constituents exist, but an average sample may be considered as containing from 0·5 to 0·75 per cent of solid matter, composed partly of saline, and partly of organic substances, namely, ptyalin, fat, and mucus, embraced in the organic class; and the phosphates of lime, soda, and magnesia, and chlorides of sodium and potassium, occupying the saline section.

Analyses of saliva by Frerichs show the amount of ptyalin to be 1·41 in each 1000 parts, and the saline matter to amount to 2·29.[1] The active substance present in the saliva—that is, the substance which acts on the principles of the food to which the saliva may be applied, is the organic substance ptyalin. It acts rapidly on the farinaceous portion of the food, resulting

[1] The saliva, as it moistens the mouth, is a mixture of the secretions from the different glands. I have examined this mixed saliva, and found in one sample 0·672 per cent of solid matter, 0·254 being inorganic, and the remaining 0·418 organic. In another sample I found 0·902 per cent of solids (the greater quantity in this than in the other sample being due chiefly to mucus), of which 0·284 were inorganic, and the remaining 0·618 organic. 200 parts by weight of this sample, produced by action upon starch, at a temperature varying from 98° to 102°, for sixty minutes, 1·20 of sugar (glucose).

in the formation of dextrin and grape-sugar. Farinaceous substances appear, indeed, to be alone acted upon by this substance, and therefore digestion in the mouth may be said to be the digestion of the farinaceous bodies only. Some idea of the rapidity of the action may be had from the fact, that in starch-paste which had been in contact with the saliva for so short a time as thirty seconds, sugar has been detected, while one part of the active principle, ptyalin, is capable of converting 2000 parts of starch into sugar. The action of the ptyalin appears to be as that of a ferment, inducing molecular changes in the starch, which are productive first of dextrin and then of grape-sugar. It has been observed that, unlike human saliva, the saliva of certain other animals does not act upon starch, and that it has no chemical action in the digestion of their food, but simply aids in the reducing of it to a state in which the other fluids may easily act.

After being mixed with the saliva the food passes into the stomach, which, from its evident importance, Lord Bacon expressively called "The father of the family," and here it meets with certain compounds, by which its chemistry is very considerably changed ; in fact it is here that by far the greatest changes are effected, although the other subsequent actions are equally essential to perfect digestion. It meets with a fluid, which, being secreted by glands on the sides of the stomach, is called "gastric juice." What is the composition of this fluid, and what are the changes which it effects in the food ?

Previous to the year 1822 no very reliable experiments were conducted on these points, chiefly from the difficulty of obtaining a supply of the fluid in its natural state for examination. In that year, however, Dr. Beaumont was enabled to collect a considerable quantity of gastric juice at various times from a man who had been wounded, and an opening caused directly into the stomach. This was an opportunity which was not to be allowed to pass, and the results have considerably extended our knowledge of digestion, at all events of that part of digestion which takes place in the stomach. While a stomach contains no food or other solid substance unacted upon, no gastric juice is secreted, but immediately (by the irritation produced on the glands) on the entrance of any solid body this fluid commences to flow, hence it may be remarked that the amount of it secreted will be in proportion to the quantity and frequency of food taken. Dr. Beaumont describes the gastric juice as "a clear, transparent fluid, inodorous, a little salt, and very perceptibly acid. Its taste is similar to that of thin mucilaginous water, slightly acidulated with muriatic acid. It is readily diffusible in water, wine, or spirits; slightly effervesces with alkalies; and is an effectual solvent of alimentary substances. It possesses the property of coagulating albumen in an eminent degree, is powerfully antiseptic, checking the putrefaction of meat; and effectually restorative of healthy action when applied to old fœtid sores and foul ulcerating surfaces."

The gastric juice possesses an organic principle

called *pepsin*, along with a little hydrochloric acid, and it is to these that its solvent action is due. The amount of pepsin in the gastric juice of human beings is about three parts in each 1000, while the hydrochloric acid amounts to only 0·2. Although apparently such a small amount of hydrochloric acid, yet it acts very considerably in the digestion of certain parts of the food, in fact without the acid the pepsin would probably be without effect. The gastric juice of animals such as the dog, contains much more pepsin than that of human subjects (nearly six times as much), which may reasonably account for the ease with which these animals (although the structure of their digestive *organs* closely resembles our own) are able to digest various substances which we should look upon as absolutely incapable of digestion. The substances upon which the pepsin and gastric juice act are chiefly the nitrogenous compounds, such as albumen, fibrin, and casein. With regard to the digestive action of the different pepsin compounds, and clearly the pepsin of gastric juice exists there in a combined state, most probably as chloride, Dr. Carpenter says—" A liquid containing only 17 ten-thousandths of acetate of pepsin, and six drops of hydrochloric acid per ounce, possesses solvent power enough to dissolve a thin slice of coagulated albumen in the course of six or eight hours' digestion. With 12 drops of hydrochloric acid per ounce the same quantity of coagulated albumen (white of egg) is dissolved in two hours. A liquid which contains only half a grain of acetate of pepsin, to which hydrochloric acid and white of egg are alter-

nately added, so long as the latter is dissolved, is capable of taking up 210 grains of coagulated white of egg at a temperature between 95° and 104°. The same acid with pepsin dissolves blood, fibrin, meat, and cheese; whilst the acid without the pepsin requires a very long time to do so at ordinary temperatures. It appears from these experiments that the acid is the real solvent, and that the action of the pepsin is limited to *disposing* the albuminous matter for solution, producing in it a change analogous to that which may be effected by heat. Hence it may be considered, like ptyalin, as a sort of *ferment*, its office being to produce a tendency to change in the substances on which it acts, without itself entering into new combinations with any of their elements."[1] Briefly, the digestive property of the gastric juice has for its purpose the softening and partial dissolving of various articles of food, chiefly the nitrogenous substances, and the resulting mixture is called chyme. With the gastric juice obtained at various times from the stomach of the wounded man, Dr. Beaumont made numerous experiments, from which he has constructed a table showing the time required for the digestion of various articles of food in the stomach. As, however, digestion does not take place altogether in the stomach, or, as digestion is not completed in that organ, it follows that his experiments can only represent the time required for a part of proper digestion, and then, as I shall presently show, only rela-

[1] I consider this point not sufficiently evident, and am engaged upon experiments with reference to it.

tively. He shows that eggs, trout, salmon, and venison were digested in an hour and a half; milk, barley, and cow's liver, in two hours; and beef, mutton, and fowl, in from three hours to three hours and a half. Since the experiments of Dr. Beaumont, which were published in a volume bearing the date 1832, and entitled *Experiments and Observations on Gastric Juice and Physiology of Digestion*, we have numerous others, but as they bear more upon the details of the processes they are not necessary to be given here as showing the general actions which occur.

In order that the digestion of food may take place most successfully in the stomach, certain conditions, in regard to temperature and motion, are necessary, as found naturally existing there. These conditions should therefore be observed in artificial experiments. The temperature most suitable is that of 100° Fahr. The contents of the stomach are kept continually in motion by the contraction and expansion of the muscles (called peristaltic motion), and as each portion of the food becomes digested it is at once removed from the stomach, so that the other portion remaining undigested is kept completely in contact with the solvent fluid. From this it must appear that in artificial experiments upon digestion the conditions cannot be the same as in natural instances, and therefore the results only relative, inasmuch as the digested portion of the food cannot be removed as soon as digested, and its presence must prevent, to some extent, the activity of the digestion of the other parts. By the action of the gastric juice the food

becomes altogether changed in appearance, and is converted into a fluid called chyme, which is composed differently, according to the nature of the food from which it is produced, but invariably containing sugar, fat, and nitrogenous substances, resulting from the action of the digestive fluids, and called peptones. The food partly digested leaves the stomach as chyme; a part of it passing, by absorption, through the walls of the stomach, the other part passing through an opening, called the *pylorus*, into the first intestine, called the *duodenum*, where it is subjected to two digestive fluids, known respectively as pancreatic juice and bile. The pancreatic juice is secreted by a gland called the pancreas—hence its name—and it has been examined by Schmidt with the following results, though its actual composition is very variable:—

Water	980·45	
Pancreatin	12·71	1000
Other organic matter, and inorganic salts	6·84	

Here the active principle is pancreatin, and the pancreatic juice appears to be generally useful as a digestive agent, acting on every class of food, namely, upon the starches, fats, and nitrogenous substances. Those farinaceous substances which have not, by the action of the saliva, been fully digested, are here arrested, and it is certain that a good deal of the digestion of farinaceous substances is accomplished by this fluid. Bile is also a most important fluid, being discharged from the liver. In digestion the bile (and consequently the organ which secretes it)

has much work to perform (also in discharging waste substances from the system), and it is, therefore, not surprising to find that the liver is usually one of the first organs to become diseased, for "all work and no play makes Jack a dull boy." The bile assists in emulsifying the fatty portions of the food, and thus brings them into a state capable of absorption. But the secretion of bile by the liver, as just mentioned, serves also the very important purpose of withdrawing from the blood certain products of the decomposition of the tissues which are constantly being formed as the wheel of life goes round. It is owing to the contamination of the blood with the constituents of the bile (which is then improperly secreted) that various nervous diseases arise, also giving rise to the yellow colour of the skin characteristic of jaundice. The composition of bile is variable, so far as regards the *amount* of its constituent parts, thus the solid matter varies from 9 to as much as 18 per cent. It contains a substance called bilin in combination with soda, and it is to this compound of soda that the action of the bile is due. The substance *bilin* exists to the extent of about 9 per cent in average instances, and the total solid matter to about 15. It is a resinous compound, composed, according to Lehman, of two resinoid acids, named, respectively, *glycocholic* and *taurocholic* acids, in combination with soda. Bile also contains, in addition to ordinary fatty substances in combination with soda, a peculiar substance called cholesterine, which closely resembles spermaceti, but is not saponifiable like other fats. It is composed almost

entirely of carbon and hydrogen—thus $C_{26}H_{44}O$. The complete chemistry of bile involves in its explanation the use of many hard words which would be inappropriate here; suffice it to say that its action is due, in digestion, to the substance bilin, chiefly upon the fats which have escaped the previous digestive processes. The digestion of the food is now completed, and the food is changed into a fluid called chyle; separated from various substances of no avail in the nutrition of the body, which are therefore cast away; the chyle being absorbed by vessels in the lower parts of the alimentary canal, called lacteals, which convey it to the blood, with which it mixes, and into which it becomes converted: how, chemistry so far cannot tell, but we know that the composition of chyle when first absorbed is almost precisely the same as that of the blood itself, and the difference is therefore apparent rather than real. Briefly, the actions to which the food is subjected before it can be appropriated to the nutrition of the body are these: it is masticated and mixed with the saliva, which contains a nitrogenous substance called ptyalin, possessing the property of acting on starch and converting it into sugar. It then passes into the stomach, where it meets with a fluid called gastric juice, in which the active agents are a nitrogenous substance called pepsin, and a little free hydrochloric acid. This gastric juice has no action on the starch of the food, but acts upon the albuminous substances, rendering them capable of absorption. The partly-digested food passes on to the duodenum, or first intestine, and is mixed with the pancreatic

juice and the bile. By the joint action of all these fluids—the saliva, the gastric juice, the pancreatic juice, and the bile—the available substances taken as food are converted into a state capable of absorption and appropriation to the blood, which supplies the various organs and tissues of the body (for "the blood is the oil of the lamp of life") while the remaining substances not so appropriated—being valueless—are thrown out.

In instances where digestion is naturally perfect, nothing of course is necessary to aid it, but in cases where the digestive faculties are impaired it is otherwise. The use of spirits as an antidote for the more common forms of indigestion has been generally advocated, also malt liquors; but in the latter case the beneficial effect seems to be due rather to the malt than to the alcohol which they contain.

The beneficial effect of alcohol[1] in cases of dyspepsia must not be taken as a ground for its general use, for no drinks, when used in excess, so seriously act upon the organs, which have for their special function the digestion of the food, as those containing alcohol; the more undiluted the more actively.[2] The use of alcohol is a topic upon which there are many different opinions, and these very widely circulated. No doubt many lives

[1] Most probably due to pure physiological action rather than to chemistry.

[2] I find that alcohol retards the digestion of farinaceous substances by saliva. The amount of glucose produced in one hour by the action of 200 parts of saliva was 1·20, but with saliva to which 18 parts of absolute alcohol were added the amount of sugar produced in the same time was only 0·857—a difference of 0·343.

have been saved by the timely use of alcohol in cases where the functions of life have been checked rapidly by some outward circumstances; but there is a wide difference between its use in cases of necessity and in those where it is taken merely for the gratification of a taste which is frequently seen to increase as it is accommodated. The evident conclusion which presents itself is that the *moderate* use of alcoholic liquors is not injurious, and in some cases is decidedly beneficial, but the word moderate is defined differently by various persons, and unfortunately often extended according to circumstances which intervene.

If we consider for a moment the delicate structure of that receptacle into which all the food we take almost immediately passes, and then the peculiarly severe action of spirit on tender parts, I think it must impress us that the tendency of the spirit must be, when little diluted, first to irritate or inflame the lining of the stomach, and to cause the delicate glands to secrete their digestive fluids less actively, while the irritating action must be guarded against by living action. Alcohol, therefore, largely used, has injurious effects.

It may be said—"You admit that alcoholic liquors, when largely consumed, are injurious, and it follows that the moderate use of them will be proportionately injurious." I question this very much. Many substances used in medicine are active poisons. Prussic acid, strychnine, corrosive sublimate, and arsenic, are the most poisonous compounds we possess. They are frequently used in medicine, but used in this way they are

not poisons, but produce certain desirable effects in removing various diseases. So, it must be admitted that alcohol, when judiciously used, is productive of beneficial effects. Malt liquors contain, along with the alcohol, various compounds, which are admitted to be alimentary, while the malt aids digestion. Beer has been for long used as a refreshing beverage, and we find (perhaps as a result) its merits spoken of in some verses written about 250 years ago! They are at least worthy of note for their originality :—

"I, iouiall Wine, exhilarate the heart.
Marche—Beere is drinke for a king.
But Ale, bonny Ale, with spice and a toast,
In the morning's a daintie thing.
Chorus—Then let vs be merry, wash sorrow away,
Wine, Beere, and Ale shall be drunke to-day.

"I, generous Wine, am for the Court.
The Citie calles for Beere;
But Ale, bonny Ale, like a lord of the soyle,
In the country shall domineere.
Chorus—Then let vs be merry, wash sorrow away,
Wine, Beere, and Ale shall be drunke to-day.[1]

Dr. B. W. Richardson, whose name is now almost a household word in regard to matters of public health, and especially in reference to the injurious effects of alcohol, published in the *Popular Science Review* for April 1872, an article upon the effects of alcohol. Although somewhat lengthy, I abridge the following as his conclusions :—

"1. In the first place, we gather from the physiolo-

[1] Dr. Edward Smith, *On Foods.*

gical reading of the action of alcohol that the agent is a narcotic. I have compared it throughout to chloroform, and the comparison is good in all respects save one, viz. that alcohol is less fatal than chloroform as an immediate destroyer.

"It kills certainly in its own way, to the extent, according to Dr. De Marmond, of fifty thousand persons a year in England, and ten thousand a year in Russia; but its method of killing is slow, indirect, and by painful disease.

"2. The well-proved fact that alcohol, when it is taken into the body, reduces the animal temperature, is full of important suggestions. The fact shows that alcohol does not in any sense act as a supplier of vital heat, as is so commonly supposed, and that it does not prevent the loss of heat as those imagine 'who take a drop to keep out the cold.' It shows, on the contrary, that cold and alcohol in their effects on the body run closely together—an opinion more fully confirmed by the experience of those who live or travel in cold regions of the earth. The experience of the Arctic voyagers, of the leaders of the great Napoleonic campaign in Russia, of the good monks of St. Bernard, all testify that death from cold is accelerated by its ally alcohol. Experiments with alcohol in extreme cold tell the like story, while the chilliness of body which succeeds upon even a moderate excess of alcoholic indulgence, leads direct to the same indication of truth.

"3. The conclusive evidence now in our possession that alcohol taken into the animal body sets free the heart,

so as to cause the excess of motion, of which the record has been given above, is proof that the heart, under the frequent influence of alcohol, must undergo deleterious change of structure. It may, indeed, be admitted in proper fairness, that when the heart is passing through this rapid movement, it is working under less pressure than when its movements are slow and natural; and this allowance must needs be made, or the inference would be that the organ ought to stop at once in function by the excess of strain put upon it. At the same time, the excess of motion is unquestionably injurious to the heart and to the body at large; it subjects the body in all its parts to irregularity of supply of food; it subjects the heart to the same injurious influence; it weakens, and, as a necessary consequence, degrades both the body and the heart.

"4. Speaking honestly, I cannot, by any argument yet presented to me, admit the alcohols by any sign that should distinguish them from other chemical substances of the exciting and depressing narcotic class. When it is physiologically understood that what is called stimulation or excitement is, in absolute fact, a relaxation, I had nearly said a paralysis, of one of the most important mechanisms of the body—the minute, resisting, compensating circulation—we grasp quickly the error in respect to the action of stimulants in which we have been educated, and obtain a clear solution of the well-known experience that all excitement, all passion, leaves, after its departure, lowness of heart, depression of mind, sadness of spirit. We learn, then, in respect

to alcohol, that the temporary excitement it produces is at the expense of the animal force, and that the ideas of its being necessary to resort to it, that it may lift up the forces of the animal body into true and firm and even activity, or that it may add something useful to the living tissues, are errors as solemn as they are widely disseminated. In the scientific education of the people no fact is more deserving of special comment than this fact, that excitement is wasted force, the running down of the animal mechanism before it has served out its time of motion.

"5. It will be said that alcohol cheers the weary, and that to take a little wine for the stomach's sake is one of those lessons that comes from the deep recesses of human nature. I am not so obstinate as to deny this argument. There are times in the life of man when the heart is oppressed, when the resistance to its motion is excessive, and when blood flows languidly to the centres of life, nervous and muscular. In these moments alcohol cheers. It lets loose the heart from its oppression; it lets flow a brisker current of blood into the failing organs; it aids nutritive changes, and altogether is of temporary service to man. So far alcohol is good, and if its use could be limited to this one action, this one purpose, it would be amongst the most excellent gifts of nature to mankind. Unhappily, the border line between this use and the abuse of it, the temptation to extend beyond its use, the habit to apply the use when it is not wanted as readily as when it is wanted, overbalance, in the multitude of men, the temporary value

that attaches truly to alcohol as a physiological agent. Hence alcohol becomes a dangerous agent in the hands of the strong and wise, a murderous instrument in the hands of the foolish and weak. Used too frequently, used too excessively, the agent that in moderation cheers the failing body, relaxes its parts too extremely; spoils vital organs; makes the course of the circulation slow, imperfect, irregular; suggests the call for more stimulation; tempts to renewal of the evil, and ruins the mechanism of the healthy animal before its hour for ruin by natural decay should be at all near.

"6. It is assumed by most persons that alcohol gives strength, and we hear feeble persons saying daily that they are being kept up by stimulants. This means actually that they are being kept down, but the sensation they derive from the immediate action of the stimulant deceives them, and leads them to attribute lasting good to what, in the large majority of cases, is persistent evil. The evidence is all-perfect that alcohol gives no potential power to the brain or muscle. During the first stage of its action it may enable a wearied or feeble organism to do brisk work for a short time; it may make the mind briefly brilliant; it may excite muscle to quick action; but it does nothing at its own cost, fills up nothing it has destroyed, as it leads to destruction. A fire makes a brilliant sight, but it leaves a desolation; and thus with alcohol. On the muscular force the very slightest excess of alcoholic influence is injurious. I find, by measuring the power of muscle for contraction in the natural state, and under alcohol,

that so soon as there is a distinct indication of muscular disturbance, there is also indication of muscular failure; and if I wished, by scientific experiment, to spoil for work the most perfect specimen of a working animal, say a horse, without inflicting mechanical injury, I could choose no better agent for the purpose of the experiment than alcohol. But alas! the readiness with which strong well-built men slip into general paralysis under the continued influence of this false support, attests how unnecessary it were to put a lower animal to the proof of an experiment. The experiment is a custom, and man is the subject.

"7. It may be urged that men take alcohol, nevertheless, take it freely, and yet live; that the Swede drinks his average cup of twenty-five gallons of alcohol per year, and yet remains on the surface of the earth. I admit force even in this argument; for I know that under the persistent use of alcohol there is a secondary provision for the continuance of life. In the confirmed alcoholic the alcohol is in a certain sense so disposed, that it fits, as it were, the body for a long season, nay, becomes part of it; and yet it is silently doing its fatal work: all the organs of the body are slowly being brought into a state of adaptation to receive it and to dispose of it; but in that very preparation they are themselves undergoing physical changes tending to the destruction of their functions, and to perversion of their structure."

The very cloudy picture thus drawn by Dr. Richardson must impress us that alcohol is a destructive agent

in the majority of cases; yet it does not remove the idea of its judicious use.

No doubt water is the natural drink, but something is necessary to flavour it to suit our tastes, and unquestionably the first compound used for this purpose was alcohol. The use of alcohol dates back therefore from the beginning of time, and it has been well said that we are fools of habit.

The important subject of water-supply now crops up as being appropriate for some consideration here, for if it is, as it unquestionably is, important that we should consume considerable quantities of water, it is not less important that this water should be good and wholesome. The questions to be asked are—

1. What is wholesome water?
2. How do we know when water is wholesome?
3. In what way does bad water affect us?
4. How can we purify bad water?

It is impossible to live without air, and it is equally impossible to live without water; they may, therefore, be looked upon as peculiar forms of food, indeed other substances cannot nourish us without water. It is only because they are supplied so regularly and naturally, that we are liable to neglect their value. We have previously noticed that absolutely pure water consists of two gases only, combined together—oxygen and hydrogen—but when we examine such water as we find naturally about us, we find it to contain other substances in greater or less proportions, and it is to the quantity and character of these additional substances that the

purity or otherwise, the suitability or otherwise, of the water for domestic use is due. Thus by analysing a sample of water, we obtain a knowledge which may enable us to say whether it is suitable for drinking purposes or not. The purest form of natural water is that which falls in the country from the clouds as rain, hail, or snow, but as soon as it reaches the earth it begins to dissolve certain substances from it, which too often are injurious to health when drunk. It may justly be said that rain-water is not pleasant to the taste, and it is often supposed, therefore, that it is not wholesome, but this is not necessarily the case. Moderately hard-water is pleasanter to the taste, and often quite as wholesome as soft water, so that the "hardness or softness" of a water does not determine its value for drinking purposes. Soft-water has, however, a greater tendency to dissolve lead and other poisonous metals, so that care should be taken that lead-pipes are not used to convey water to be used for drinking or culinary purposes. Although water should be clear, colourless, and of good taste, yet a water may answer all these tests, and still be unsuitable for domestic use ; the taste and sight are, therefore, not certain guides for us in judging of a water, although, too often, water answering them satisfactorily, is considered right, even where circumstances connected with the district from which it is derived may cast a doubt upon it. In country districts the subject of water-supply appears to be frequently left to the evidence and decision of those who know nothing of what really determines good or bad water, and who use as conclusive

tests the faculties just named,—they say "chemists may be wrong, but our taste and sight—impossible!"

We are told that the action of bad water is sometimes very slow,—it may gradually wear away a good constitution, or, on the other hand, its action may be rapid, when the impurity favours it, by inducing serious disease, such as the cholera, the spreading of which is invariably traced to the use of bad water. Rain-water when it falls upon the earth is absorbed by it, and percolates through it to supply wells. In this percolation through the soil it may meet with drainage from animals, in which case it becomes charged with substances which in time, as they putrefy, become more and more pernicious. That portion of the rain which is not absorbed by the soil runs down the hillsides to form rivulets, which join together to form rapid streams. These streams pick up, till they run into their ultimate reservoir, the sea, various impurities, so that river-water must at all times, except in unpopulated districts, be looked upon with the suspicious eye, which condemns its use for drinking purposes. As cattle gradually turn their weary steps to the nearest water, so we find man has from time to time, from the beginning of time, settled by the banks of streams, and as a result of his artificial constructions, and his own pollutions, once crystal streams are turned to foul and putrid sewers. Public wells, for when we speak of things public, we mean something near and handy to a considerable population, are, especially when shallow, not desirable things, for they are very liable to drainage

from houses in the vicinity, and therefore, in the time when disease is in the neighbourhood, to contamination by the germs of such disease, which, when taken into our bodies, are planted in their natural soil. Water for a populated district should be obtained from a district quite apart from it; from one where there can be no pollution by animals, thus most of our large towns are now supplied from the Lake Districts, and animals grazing on the land on which the water collects are removed.

Bad water is, when not absolutely productive of disease, a very fruitful means of spreading it, for, as the atmosphere is the great receptacle into which all gaseous emanations are discharged, so into the water, the fluid and some solid impurities naturally find their way. But while in the former purification naturally goes on rapidly, in the latter the purification under the best circumstances is comparatively slow. Dr. Simons, the medical officer of the Privy Council, says—"It is, I believe, a matter of absolute demonstration, that in the old epidemics, when the south side of London suffered so dreadfully from cholera, the great cause of the immense mortality there was the badness of the water then distributed in those parts of London. In the interval between the 1849 and the 1854 epidemic, one of the two companies which supply the south side of London had amended its source of supply; it had gone higher up the river, and we at once lost a great part of the mortality on that side of the river. But it was found that this great difference did not prevail uniformly throughout the

south side of London, but was confined to those houses which were supplied from the amended source. There was still a great mortality on the south side of the river, but this belonged exclusively to the houses which were still supplied with impure water." This is therefore one instance amongst many others of the promotion of disease by the use of bad water.

Having seen that the sight and taste are not certain guides to tell us when a water is suitable for general domestic use, we ask what chemistry can tell us upon this subject. Chemistry cannot tell us whether the water contains the absolute germs of any disease, but it can tell us whether it is contaminated by sewage or other animal substances, the presence of which is sufficient to condemn it when disease germs are absent. Speaking generally, organic matter is what we have to look for in a water as a test of its suitability, or otherwise for drinking, but it is important to note that certain forms of organic matter are comparatively innocuous, while others are highly pernicious. Water, for instance, may contain organic matter in the form of peat, even to such an extent as to be distinctly coloured (as we often see country streams running from boggy lands) and yet be almost harmless, while water containing a very small fraction of that amount of another sort of organic matter may be, and indeed has often been found, absolutely poisonous; hence, we must observe that the mere *existence* of organic matter is not *proof* of the unwholesomeness of the water. The nature of the organic matter must be carefully determined before we can say that it

is injurious, although it is better to be on the safe side, and to have, when possible, water absolutely free from organic matter. I believe Dr. Angus Smith was the first to point out the importance of determining the nature of the organic matter, and not simply the total amount, in potable waters, and he arranged it under the following heads :—

a. Putrid.
b. Ready to become putrid.
c. Slow to become putrid.
d. Partly oxidised.
e. Oxidised more completely.
f. Of vegetable origin.
g. Of animal origin.

These distinctions are most valuable, and no doubt afford ample data to decide from as to whether a water is good or bad for drinking purposes, but answers to the questions, Does a water contain *nitrogenous* organic matter? and, Is it putrid? are generally sufficient to determine the suitability of a water.

A determination of the amount of chlorine (as chlorides) is also often desirable, since chlorine is a considerable constituent of sewage, and it therefore affords, when properly applied, an index of the sewage contamination.

Nitrogenous organic matter, when it decomposes, forms ammonia and nitrates, so that it is simply necessary, for ordinary purposes, to determine the amount of free ammonia in a sample of water as an index of the decayed organic matter in it. The nitrogenous organic

matter *not decayed* is arrived at by decomposing it artificially, and determining the amount of ammonia which it produces. Thus, in the results of an analysis, the nitrogenous organic matter *not decayed*, is shown by the "*albuminoid ammonia*," and the decayed organic matter by the "*free ammonia*," as under.

	Good Water.	Bad Water.
Albuminoid ammonia	0·03 (parts per million).	0·10 (parts per million).
Free ammonia .	0·01 ,,	0·08 ,,

This "ammonia process" of water-analysis is strongly recommended by Professor Wauklyn, who, along with Mr. Miles H. Smith, first suggested it, and it has found general acceptance at the hands of "Medical Officers of Health," owing to its requiring little manipulation, and possessing few details.

As already said, a determination of the amount of chlorine in a sample of water is often valuable in judging as to the suitability of such water for drinking purposes. If we find much "free ammonia" and much chlorine, we may conclude that the water is contaminated by sewage matter or other animal refuse; but a large quantity of chlorine, when ammonia is absent, does not lead us to conclude in the same way, for chlorine is a constituent of many wholesome waters, and invariably present in considerable quantity in the waters of wells near the sea, and of those in salt districts. Chlorine indicates the presence of common salt, and as common salt is in daily use as a necessary substance for our consumption the mere presence of chlorine in a water does not necessarily condemn it. Its presence must be

looked upon as indicating the presence of other substances which are injurious before we can condemn its own presence, and therefore, as just said, if ammonia be not found along with it, as a result of decaying organic matter, the presence of a considerable quantity of chlorine need not be looked upon as a stumbling-block in the way of the use of a water containing it.

The water of a well, the bottom of which was about 24 feet above the level of the sea, and distant about half a mile from it, was made the subject of a number of experiments, and I found that on no two days, during three weeks, was the amount of the chlorine nearly the same. The greatest variation of chlorine, which was during sixteen days, was from 5·95 to 17·5 grains per gallon, whilst the other constituents, such as sulphates, remained almost the same. The soil in the neighbourhood of the well was alluvial, and it may have been that there was actual infiltration of sea-water, since the difference appears greater than could reasonably be due to rainfall. It is, however, also possible, as suggested by Mr. C. E. Groves, after my paper was read on the subject at the Chemical Society,[1] that the waters of wells near the sea might derive much of their chlorine from the scud driven over the land in stormy weather, and which settling on the land would be washed in, along with the surface water by subsequent rains. The water in question was not contaminated by organic matter, so that the variations of chlorine were not due to the occasional infiltration of sewage matter. The locality from which

[1] February 15, 1877.

the water is obtained must be considered before the chlorine test can be applied to give any certain conclusions in water analysis.

It is important that a water for drinking purposes should be free from smell, as any unpleasant smell in water generally arises from organic pollution. A very useful test, which we may easily apply, is to keep some of the water to be examined in a glass bottle and expose it to the light and warmth. After a few days' exposure determine whether it remains clear and free from smell when shaken in the bottle. If not, there is sufficient ground for disputing the wholesomeness of it, and of having the matter decided by a proper chemical examination.

As there are causes in nature which render pure water impure, so there are natural processes at work by which impure water is purified. Water contaminated by organic matters is purified from these in nature by the gradual oxidation of them, and by filtration through porous strata; the oxygen necessary for this purification being supplied primarily by the atmosphere, which is the grand purifier of everything existing upon the earth. Distillation is also a natural means of purifying water, for evaporation takes place from all waters, resulting in vapours which form clouds, and when condensed these return water to the earth effectually purified. Artificial purification of water is effected in exactly the same way; we resort to distillation, and to filtration, and oxidation of the impurities. By the first method we obtain water of the highest degree of purity, such as is used in cases of most

accurate and delicate chemical analyses, but it is seldom adopted as a means of purifying water for drinking purposes. It is employed at sea; a quantity of the sea-water being distilled as required in preference to carrying a supply of pure water ready for use, since the fuel necessary will distil considerably (8 or 9 times) more than its weight of water, and thus a saving in carriage is effected. The filtration of water through animal charcoal (charred bones)—of which the filters now sold for domestic use are generally made—is effective in oxidising the organic impurities contained in it, and thus rendering them harmless. It is very questionable, however, whether such filtration would arrest the germs of a disease, for these germs are alive, and just as an egg may be easily operated on when beaten up, yet when unbeaten up much more time would be required to do this, so organic matter, such as is present in ordinary sewage, would be acted upon by these filters, but it is not probable that the living germs of disease, which are very different, would be so acted upon. Thus the value of these filters must be restricted. Animal charcoal contains the active oxygen absorbed and condensed, as it were, in its pores, so that the water passing through the charcoal is subjected to this oxygen, which, as has just been said, oxidises the organic impurity present, and therefore purifies it. The same action goes on as that which occurs in an ordinary fire—in popular language, therefore, the organic matter may be said to be burned. By being used for some time the charcoal becomes inactive, in which case it is necessary to remove

it from the filter and to expose it for some days to the air, from which it absorbs fresh oxygen, and after which it is again effectual. Filters composed of iron in a spongy form are now used for the purification of water ; they act in precisely the same way as those composed of charcoal.

CHAPTER V.

"　.　.　.　.　.　How the world wags.
'Tis but an hour ago since it was nine;
And after an hour more 'twill be eleven,
And so, from hour to hour we ripe and ripe,
And then, from hour to hour we rot and rot,
And thereby hangs a tale."—SHAKSPEARE.

AS Time gradually rolls on, and as one hour silently gives birth to another, so life and death are closely connected. "Time and tide wait for no man," neither can life be arrested on its onward flight. The substances of a worn-out body, however, return to the earth, from which new life is continually rising in the form of vegetation. From the fact that living bodies present various functions of which lifeless matter is destitute, dead matter and living matter are very generally regarded as belonging to totally different categories, but chemistry shows us that both are composed of the same elements, the only difference being the presence of a peculiar principle in the one which is not present in the other—this principle being called *vitality*.

Like the philosopher's stone of old, this vitality has been for long the object of research without success, for, even at this advanced period of society we ask—almost without the hope of an answer—What is that by which we think and understand? What is it that

endows the yolk, the white, and the membrane of the egg with motion, which brings forth in them nerves, muscles, and bones? It *is* possible to answer a number of questions bearing upon the nature of life, but before we come to the final point we find a link missing which, so far, no one has been able to replace. But just as the endeavours of the ancients to hit upon an elixir of health—a substance which would itself cure every conceivable disease—brought forward several important matters in connection with the science of hygiene, so we may, aiming at the light of life as the ultimate object, pass through a strata of material to form much valuable knowledge now unpossessed, and of which we have no conception. This research is to be commenced by the intimate study of nature.

Nothing is more evident than the temporary existence of all living bodies. Certainly some living species endure longer than others, but all must ultimately decay. Some animals live hundreds of years, while others only a few hours; their dawn is with the dawn of day, and their death at its close. Between these two extremes there are many animals whose tenure of life is a medium, and we unhesitatingly believe that even those whose life is of the shortest duration have their special work to perform in the economy of nature,

> "For nought so vile that on the earth doth live,
> But to the earth some special good doth give."

The chemistry of all these bodies is practically the same; the vitality which in certain particulars governs

the chemistry of them is in each instance the same, simply varying in extent; but in man there is in addition that precious and characteristic gift which suggests his actions, by which he accumulates knowledge, and through which he has increased hope. He does not act upon instinct alone, but from a knowledge of that which has past; while, by the proper use of the imagination, he is able to build ideal objects for future realisation. As the sun rises with brightness in the morning, gradually increases in intensity till noon, and fades away at eve, so our lives are variable in their course; they include periods of brightness, activity, and fading, while the fading, as the fading of a day, is followed by freshness of life, which prevents both loss of matter and loss of energy. The functions of life are lessened at night, to be more vigorous in the morning, and as day and night have therefore particular ends to promote, so the different seasons are desirable changes. During the spring and the summer the plant grows; in the autumn it has arrived at maturity and provided for a future generation by the formation of seeds; while in the winter the substance of it decays to promote the growth of other plants in the following spring; and so this natural process of growth and decay goes on from year to year, affording in each fresh life and beauty.

Nothing in nature is actually destroyed, though everything is constantly changing. We cannot create or destroy anything; we cannot create the chemical substances of which we are composed, neither can we create that energy which keeps them in their wonderful

order. The substances are derived in every case, either directly or indirectly, from the earth, to which they finally return, to spring forth in fresh organisms. The energy, as already said, is very little understood ; for, although we can determine the changes which go on in our bodies to form that fluid which supplies each part of them with materials for its repair and growth, yet no one can tell how this fluid is kept constantly circulating ; how it is that the precise substances are always carried to the particular parts requiring them, that the phosphate of lime is always deposited or added to the bones to enlarge them, and the fibrin to the muscles. Probably each part acts as a germ of its own kind, as a magnet of a particular attractive property. Yet this peculiar selective faculty is not a distinct characteristic of living nature, for, crystals of various substances have definite forms, and if one of these be slightly damaged, and dipped into a saturated solution of the same compound, it will completely repair its damaged parts. Alum is a good example of such a crystalline substance. And further, although the solution may contain other substances, the crystal repairs itself with matter of its own kind only, and refuses to appropriate the other substances unless they belong to the same crystalline system.

There are three kinds of animals—herbivorous, carnivorous, and omnivorous. We are " omnivorous," because we are able to use articles as food, for the supply of necessary materials to our bodies, belonging to either the herbivorous or the carnivorous class ; that is, the

formative substances we require may be appropriated by us, either directly from the vegetable world, or indirectly, after having passed into and accumulated in an herbivorous animal. If seeds be sown upon soil which does not contain the necessary substances for their growth into perfect plants, the seeds will germinate, but the plants will not flourish, but cease to grow, and die before they are of any value, and similarly, we, as animals, require food ; and if it is not regularly supplied to us, we either die of actual starvation, or become organically diseased, owing to the blood becoming impure from insufficient nutrition. The causes of death — excepting when some important organ is mechanically injured by accident—are certain improper conditions in which the living functions are performed, which either prevent the regular circulation of the blood, or its proper exposure to the air ; death may, indeed, be understood as owing to the *impurity* of the blood, however caused in the first instance. Such impurity may be caused (1) by withholding sufficient nutriment ; (2) by the inability of the organs to appropriate the necessary nutriment when supplied ; (3) by the inability of the respiratory organs to act in thoroughly exposing the blood to the air by which it may be purified ; and (4) by the administration of noxious substances called poisons.

With regard to starvation, or the gradual withering away of the body by insufficient nutrition, we have seen in Chapter IV. the relative extent to which the various parts of an animal body are diminished under

these circumstances, from the experiments of M. Chossat.

The blood of animals and the sap of plants are fluids composed only of substances which are absolutely required, so that the absence of any one is as fatal as the absence of the whole. Oxide of iron is a constituent of the blood, but in some instances this compound is not appropriated to it, and, as a consequence, individuals become pale, and if the non-appropriation continues, death must speedily result, since one of the important compounds of the blood becomes absent. Oxide of iron was shown in Chapter III. to be a constituent of a most important compound, called hæmoglobin, found in the blood corpuscles, by which the functions of respiration are carried on. The particular function of the hæmoglobin of the blood is to convey oxygen to various parts of the body, which, as it passes through the body, meets with waste materials or impurities. With these the oxygen combines and renders them easy of emission. If, therefore, the blood is insufficiently supplied with this compound (which contains oxide of iron), it must follow that the purifying process cannot go on so successfully, and consequently the blood will become more and more impure, and cause a disarrangement of the whole body. The lungs, again, in which the blood first meets with the air, may become diseased, and therefore cannot expose the blood so freely to the air,—this, for the same reason, causes an accumulation of impurities, and a gradual and general debility of the body throughout.

Different poisons act in different ways. We have mineral poisons, of which arsenic and "corrosive sublimate" are a type; we have organic poisons, such as strychnine and prussic acid, others as contagions and infections; and putrid substances evolved from even healthy bodies, as well as gaseous poisons evolved from animals by their respiration, or by their actual decay. From each other these are naturally all very different, yet they have particular injurious effects on animal organisms, and are therefore all included under the name of *poison*.

Poisons are very numerous, almost every substance injudiciously used acting as such; but a complete description of those which destroy life, when administered even in small quantities, would, indeed, be very lengthy and unnecessary here. The best work on that subject is, probably, the very comprehensive edition *On Poisons*, by Dr. Alfred S. Taylor.[1]

Briefly, the general action of such substances as arsenic and "corrosive sublimate" is the coagulation of the albuminous substances of the blood—by combining with them—which, besides losing its chemical properties, is unable to circulate. Blood, partly coagulated, passing through the different organs, must speedily cause a disarrangement which cannot be borne, and actual death is invariably the immediate result.

Acting upon this view of the action of mineral poisons, it is usual, as soon as possible after such substances have been known to have been taken, to admin-

[1] Churchill: London. 1875.

ister, as an antidote, some albumen in the convenient form of the white of egg, which, by being itself coagulated, arrests in the stomach the noxious substance, and prevents its action on the blood.

Strychnine, prussic acid, and similar substances, are called *neurotic* poisons, because their action is chiefly on the nervous system. As poisons they are usually fatal, by the extreme nervous and muscular excitement which they produce. Contagions or infections consist of organisms endowed with life, having the property of reproducing themselves to an enormous extent in the blood of human beings. They are given off from the skin and in the breath of persons diseased, they contaminate the air, and are not readily destroyed by it, as putrid organic matters are. Infectious diseases, therefore, frequently become epidemic, and are only stamped out by the unsparing use of substances, such as chloride of lime or carbolic acid, which act as disinfectants.[1]

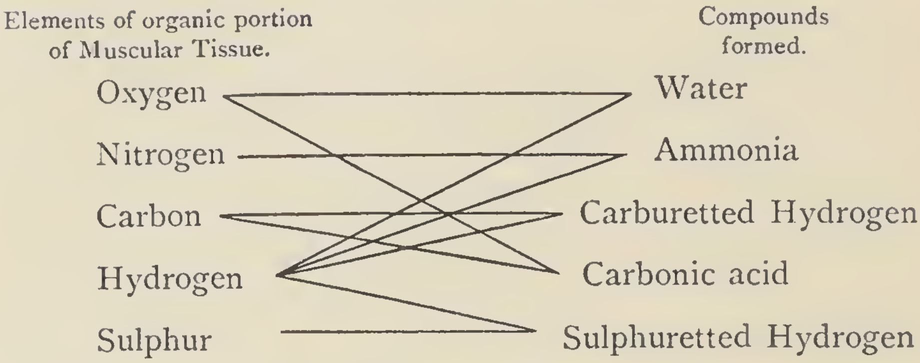
Putrid organic matter and carbonic acid gas, when contained in the air to any considerable extent, are poisonous, as mentioned in Chapter III. Being discharged from persons, even in a healthy state, they necessitate the constant renewal of fresh air in all inhabited rooms. Poisons are, however, an unnatural cause of death, although in a certain sense, all causes of death may be said to be unnatural, for, as life is the highest gift of nature, death is the means of removing it. But it must be admitted, that without death, there could not be a

[1] Chloride of lime and carbolic acid must not be used at the same time, as the one destroys the effect of the other when so used.

continuance of life, inasmuch as death and decay are in reality the means by which life is promoted, and therefore, in this way death is the natural progenitor of life.

Our bodies die, and then they putrefy and decay. The chemistry of these changes, although very different from that of those incurred during life, is important for consideration here, since these changes are those by which a constant circulation of matter is kept up in nature,—from the dead to the living, and from the living to the dead. They are due to the action of the substances of which our bodies are composed upon each other, having been previously separated and prevented from so acting, by the living action accompanying them. This living action may be said to be a superior action, having some control over the chemical action, which would otherwise occur. When this superior action is removed, the substances lose their natural government, and, speaking metaphorically, form a republic; the result being the chemical action as it occurs in decomposition or decay. The organic portion under these circumstances assumes the gaseous form, while the inorganic portion crumbles to dust: the gases flow into the air and the dust returns to the earth, thus making good the assertion in scripture, as to the origin and destination of man's material part.

The muscular tissue consists largly of those albuminous substances, fibrin and albumen, mentioned in Chapter I., and we shall have no difficulty in understanding the changes which occur by their putrefaction, or decomposition, from the following equation :—



We notice that hydrogen is an element in all the compounds formed: (excepting in the carbonic acid,) with oxygen it forms water, with nitrogen it forms ammonia, with carbon it forms carburetted hydrogen, and with sulphur it forms sulphuretted hydrogen. Now, water consists of oxygen and hydrogen, and when such water is present, these putrefactive changes occur most rapidly, because it affords the necessary hydrogen, which the carbon, the nitrogen, and the sulphur require; as without the water, the proportion of hydrogen is too little to take the whole of the other elements. Owing to this, organic bodies when dried by any artificial means are less liable to decay, or decay less rapidly than those which are not deprived of their water. By keeping such bodies frozen also, we prevent them from decaying because the water in them is solid, so that animals have been picked up hundreds of years after their death, in the ice of Siberia, and in other countries of the frigid zone, effectually preserved by the cold.

All of the compounds just mentioned, namely, the water (as vapour), the ammonia, the carburetted hydrogen, the sulphuretted hydrogen, and the carbonic acid, being gaseous, pass away and mix with the atmosphere,

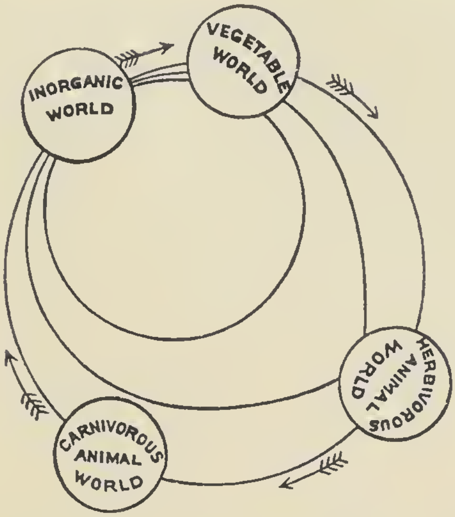
in which they are lost, to our senses in its greatness, but they are in fact there for an important purpose—the nutrition of plants, which removes them. While these substances go into the air, the inorganic portion of our bodies goes to the soil. Seeds are sown in the soil, and by the moisture it contains, they germinate, that is, they shoot out two parts, having distinct functions to perform. One, the root, dives down into the magazine of inorganic food—the soil—the other, the plumule, rises into the air to form the stem and leaves. The function of the root is, as already said in Chapter II., to absorb in a liquid form the necessary inorganic substances from the soil, while that of the leaves is to absorb those gases (or some of them) directly from the air, which were given to it by the decaying bodies; and from these gases the plant has the power, under the influence of solar-light, of elaborating the organic portion of the plant,—those useful substances, such as starch and sugar, or those compounds deadly or life-sustaining according to the manner in which they are used—as poisons or as medicines.

> "Nought so good, but strained from that fair use,
> Revolts from true birth, stumbling on abuse;
> Virtue itself turns vice being misapplied;
> And vice sometimes by action dignified."

When the conditions are most favourable, that is when sufficient air and water is admitted, the decay of a dead animal body goes on rapidly, so that in a few days it may lose its natural appearance, and finally its complete structure, the substances returning, as just

said, to earth and air, ready for appropriation by plants. Thus, a little while after death, our true representatives may be the plants which grow upon the surface of the earth. What a small portion is that which goes directly to the earth in comparison with that which flies into the air! By the gradual decay, this residue is precisely the same as that which would have remained if the body had been actually burned; in each case the organic is separated from the inorganic. Cremation is a word which, when applied to the disposal of the dead, grates upon many a delicate ear, and brings to mind the inevitable doom of every living thing, but as a measure of natural economy, it is certainly preferable to the present method of disposing of the dead; yet, being tender ground, Sir W. Thompson may here be judiciously left to advocate, as he is so well able, his own theory or suggestion.

The constant circulation of matter in nature, which is the means of continuing life upon the earth, is a subject, which although simple enough in its general outline, presents much food for enquiry as to details. The following figure shows the circulation of matter from the vegetable world to the animal world, and from the animal world to the dead world, or inorganic state, and back again to plants. Plants may either die, and return immediately to the inorganic, or they may be eaten by the herbivorous animals; these may either die or be eaten by the carnivorous animals, which ultimately die and return to the soil; Thus—



Nothing, perhaps, is more simple than the circulation of matter in nature as shown by the above figure, yet when we come to trace the many different processes through which it passes, and compounds formed by those living bodies which aid its circulation, the subject becomes more and more involved in detail, and subject for deeper and deeper thought and study. It is argued that nature presents many things for our reasonable consideration to deter us from diving into those which are evidently beyond our actual reach and control.

Dr. Spottiswode in his address to the British Association this year at Dublin, says—" He is perhaps the wisest, and in the long run the happiest among his fellows, who has not only learnt this science (mathematics), but the larger lesson which it teaches, namely, to temper our aspirations to that which is possible, to moderate our desires to that which is attainable, to restrict our hopes to that of which accomplishment, if not immediately practicable, is at least distinctly within the range of conception," and very few would venture to dispute the

value of the lesson, yet I am tempted to suggest, that while there are many things with which we cannot definitely or directly deal, yet the objects with which we can so deal are given us, not only to experiment and reason upon, but for the higher purpose of reasoning from, by which a ray of light may at least be shed upon those which are beyond our actual observation.

It is a very old proverb that "many mites make a mickle," and it is so true that we even believe that everything around us is composed of a number of atoms which are smaller than we can see, and the smallest things we can imagine. They are combined together, so that even our own bodies and the earth which they inhabit are composed of a vast number of these minute bodies of various kinds. Conditions are frequently brought about in nature by what appear most simple means, and it has often proved in scientific research that the most simple experiment has taught the greatest lesson. Accident has indeed revealed many important secrets. Watt, who observed the lid of the kettle rise by the pressure of the steam from the water boiling in it, was from this the inventor of the steam-engine, and thus the simplest imaginable experiment was productive of that industry upon which depends the prosperity of our country. The simpler the experiment the better, but an experiment is valueless unless it is properly applied, and the result intelligently considered. The lid of the kettle had often been taken off owing to the pressure of the steam long before Watt thought about it, yet the force was never thought of any value, while

many an apple had fallen from the tree before Isaac Newton wondered why it did not rise upwards, and yet the laws of gravitation were not thought about. Such simple circumstances are constantly occurring around us, and the world outside, therefore, gives us subject for endless thought and investigation. If we enjoy the simple variations of colour presented by the vegetation which clothes the earth, the fresh green of spring, the blossoms of summer, or the autumnal leaf which gives such choice variation in tint, how much more pleasure may we have in studying and in understanding the causes of those changes, and the ends they serve in the balance of all things.

Observations of nature in its various aspects; natural objects exposed to artificial influences; notes of these, and careful consideration as to the true light which they afford, are the materials by which the edifices of all science are constructed. The habit of making notes of natural phenomena as they occur cultivates a general system of useful observation, and the notes so made may frequently be of service for future consideration. Nature presents both in its living objects and in the actual heart of the earth endless scope for investigation—here are the "footprints on the sands of time" which form the hunting-fields for the mind, and our object should be to realise the words of our great dramatic author, as spoken by the banished Duke—

> "Tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything."